SPENT FOUNDRY SAND

ALTERNATE USES STUDY

JULY 1993

Ontario

Ministry of
Environment
and Energy

Ref. 72864

ISBN 0-7778-1383-1

SPENT FOUNDRY SAND
ALTERNATIVE USES STUDY

JULY 1993

Cette publication technique
n'est disponible qu'en anglais.

PIBS 2668

SPENT FOUNDRY SAND
ALTERNATIVE USES STUDY

Report prepared by:

John Emery Geotechnical Engineering Limited
#1, 109 Woodbine Downs Boulevard
Etobicoke, Ontario M9W 6Y1

for

Ontario Ministry of the Environment and Energy
and
Canadian Foundry Association

JULY 1993

"ACKNOWLEDGMENT AND DISCLAIMER"

EXECUTIVE SUMMARY

Alternative uses of spent foundry sand have been investigated considering the following elements:

1. location and quantities of spent foundry sand being generated in Ontario, and characteristics of the spent foundry sand generated;
2. current spent foundry sand management practices in the Ontario foundry industry;
3. identification of current and emerging uses of spent foundry sand through review of North American and International technical literature, and current and emerging Ontario technologies; and
4. evaluation of the technical and environmental feasibility of these alternative uses for Ontario spent foundry sand, including identification of approval mechanisms for each alternative use.

Approximately 383,615 tonnes of spent foundry sand were generated by Ontario iron and steel foundries in 1991, with less than 10,000 tonnes generated by the nonferrous foundry sector. Of the total iron and steel foundry sand generated, 95 percent is located within the Ontario Ministry of Environment and Energy Southwestern, West Central and Central Regions.

Current Ontario uses of spent foundry sand include hot mix fine aggregate (the passing 4.75 μm aggregate component of hot-mix asphalt) and cement kiln feed. Alternative uses range from supplementary concrete fine aggregate in non-aesthetic applications, bricks and mortar, mineral wool products, flux material in precious metal recovery operations, and hazardous waste vitrification. It appears from an environmental classification and approvals viewpoint, that spent foundry sand could be classified as 'recyclable material' which exempts it from the requirements of Ontario Regulation 347 and Part V of the Environmental

Protection Act. As such, use of spent foundry sand as a partial replacement for natural sand and gravel or crushed stone in the production of pavement subbase and base material supplants the hot mix fine aggregate and cement kiln feed uses as the most promising (highest volume) prospective areas where spent foundry sand could be utilized. While use as hot mix fine aggregate and cement kiln feed have the potential to utilize the complete annual production of spent sand, there are product and transportation constraints that have an impact on practical recycling in these applications. Use in granular base and subbase could potentially utilize far more than the current annual Ontario spent foundry sand production, without the same transportation cost constraints.

Regardless, it is clear that there are a number of current and emerging uses for spent foundry sand that recognize the value of spent foundry sand as a byproduct, rather than a waste requiring disposal. Full utilization of spent foundry sand requires that the spent foundry sand generators recognize not only the value of the byproduct, but the costs associated with disposal, in order to optimize the practical reuse and recycling of their spent sand.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

SPENT FOUNDRY SAND ALTERNATIVE USES STUDY

1.0 INTRODUCTION

The foundry industry in Ontario consists of about 35 ferrous (iron and steel) and 50 nonferrous (mostly copper, aluminum and brass) foundries and produces approximately 500,000 tonnes of product annually. Centred predominantly in southern and central Ontario, the foundry industry generates nearly 400,000 tonnes of spent foundry sand each year, most of which is being disposed of through municipal or private landfills, with a relatively small portion of the spent sand reclaimed for foundry reuse or recycled for other purposes.

Foundry sand consists primarily of clean, high quality silica sand or lake sand that is bonded to form moulds for ferrous (iron or steel) and nonferrous (copper, aluminum, brass, for instance) metal castings. Olivine sand, chromite sand or zircon sand are also used in much smaller quantities. Virtually all of the new foundry sand in use in Ontario is imported from the United States at a significant cost (both for the product and its transportation). These sands are clean prior to use but after casting, contain a number of components such as tramp metals, clays, seacoal and cereal flour, and residual binder materials that are introduced to the sands during moulding and or picked up from the metal casting. These components can preclude the total reuse of spent foundry sand in the foundry (reclamation of spent foundry sands can be completed but its effectiveness depends greatly on the specific types of foundry sands, binder processes and reclamation systems involved).

Spent foundry sand is frequently reused in the moulding shop, but the casting quality degrades if too much spent foundry sand is used. Consequently, most spent foundry sand is disposed in municipal or privately operated landfills after four or five casting cycles (noting

that new foundry sand must also be added to augment the spent foundry sand for each casting cycle). Existing landfills are rapidly reaching their capacity, and the Government of Ontario has adopted a 3Rs mandate (reduce, reuse and recycle - definitions given in Appendix A) to reduce the amount of material going to landfills and extend their service life. The Minister of the Environment stated on February 21, 1991 that the volume of material being disposed of in landfills must decrease by 25 percent by 1992, and 50 percent by 2000 [1]. To comply with this directive, many municipalities have substantially increased their tipping fees for 'waste' materials such as spent foundry sand to decrease the amount of material being sent to their landfills. Metropolitan Toronto, for instance, increased its tipping fee by nearly 300 percent to $ 150 per tonne on April 1, 1991. This tipping fee increase is intended to encourage waste generators to be more responsible and find more environmentally acceptable methods of managing wastes and byproduct materials.

Furthermore, the Government of Ontario has a mandate to support 'sustainable development' - using natural resources in such a way as to meet current economic and social needs, but not depleting or degrading these resources to the point that they cannot meet these needs for future generations. While new foundry sand is imported from the U.S.A., spent foundry sand reuse and recycling can provide materials to replace local natural aggregates and therefore is a factor in the conservation of Ontario natural stone and sand resources. A recent study was completed for the Ontario Ministry of Natural Resources (MNR), Aggregates Resources Section that designated current byproduct or waste materials that are being, or could be, used as replacements for natural aggregates in bulk and cementitious applications [2]. Spent foundry sand recycling was identified as one of the most promising potential recycled aggregate sources (along with waste asphalt, concrete, steel slag, nickel and copper slags, fly ash and bottom ash).

The objectives of this Spent Foundry Sand Alternative Uses Study are:

- To identify all existing and emerging spent foundry sand generators in Ontario and to characterize the spent sands being generated;

- To identify current spent foundry sand waste management practices in the Ontario foundry industry;

- To identify alternative uses, new and emerging, for spent foundry sands in use in Ontario, elsewhere in Canada, in the United States and in other advanced countries; and

- To evaluate the technical and environmental viability of these alternative uses for spent foundry sands generated in Ontario, including an identification of approval mechanisms for each viable alternative use.

Studies of a similar nature have recently been completed in Illinois and Wisconsin [3,4], with another study underway in Michigan.

2.0 THE ONTARIO FOUNDRY INDUSTRY AND SPENT FOUNDRY SAND GENERATION

The foundry industry in Ontario was described in substantial detail in a 1988 study by the Ontario Ministry of Northern Development and Mines [5]. The foundry industry encompasses at least four basic metallurgies (iron, steel, aluminum-based, and copper-based) and casting systems (sand cast, permanent mould (die casting), investment (shell) casting and lost foam). The foundry industry provides a wide range of products for many sectors of the economy, and the technologies involved in manufacturing these are often quite dissimilar, having different metallurgies and raw materials needs.

In 1988, the industry consisted of about 75 ferrous (iron and steel) foundries and 60 nonferrous (aluminum and copper-based) foundries, producing castings of all types with a value close to $ 1.8 billion. At this level, the industry was operating at a capacity utilization of only about 72 percent. Since 1988, the number of Ontario ferrous foundries has dramatically decreased to about 35, with less than 50 nonferrous foundries still in operation. The principal reasons presumed for the serious decline in this important industry are the recent poor manufacturing economy (recession), increased competition from more modern U.S. and offshore foundries, and plant and equipment obsolescence.

The largest generators of spent foundry sand, in terms of volume, are the ferrous foundries, comprising upwards of about 95 percent of the total amount of spent foundry sand produced, approximately 380,000 tonnes per year. Iron or steel castings are produced by melting the steel scrap, alloys and other additives in an appropriate melting furnace such as a cupola or electric coreless induction melter, then transferring the molten iron or steel in ladles to be poured into moulds. The moulds are fabricated using foundry sand, typically silica sand or lake sand, bonded together using a small amount of clay or organic chemical binder.

Ontario ferrous foundries basically use two types of moulding processes: a mechanically bonded process or 'green sand' system, and chemically bonded processes involving various organic binders and catalysts.

The mechanically bonded process or green sand system typically involves adding up to about 10 percent bentonite clay (as the binder) and 5 percent seacoal (a carbonaceous mould additive to improve casting finish) to silica sand. This mixture is then mechanically formed into the desired shape against a pattern and pressed to make the hardened mould.

Chemically bonded processes include a wide range of systems and usually involve the use of one or more organic binders in conjunction with catalysts and different hardening/setting procedures. Foundry sand makes up about 97 percent of the mixture. The chemical binders are usually proprietary, and include 'cold box' systems where the foundry sand/organic binder mixture is air cured or gassed at ambient room temperature to cure it, 'no-bake' systems where the mould is cured at relatively low temperatures, and heat-activated ('hot box' and 'warm box') systems where the mould is baked to harden it. Table 1 gives a partial list of binder systems commonly used in the foundry industry.

The mechanical green sand process dominates mould production in the iron and steel industry, with cold box, no-bake and shell casting (resin coated sands) systems the most common processes used in the manufacture of cores.

The finished moulds and cores are assembled in the foundry, and the molten metal is cast. After cooling to a hardened state, the castings are removed in the shake-out process where the foundry sand moulds and cores collapse. This moulding and core sand is either returned to the mould shop for reuse (moulding and core sands can be reused up to about

TABLE 1

TYPICAL CHEMICAL MOULD AND CORE BINDER SYSTEMS

	Thermosetting	Self Setting	Vapour-Cured (Cold Box)
Organic	Shell Hot Box (furan/phenolic) Warm Box Core Oil	Furan No-Bakes High nitrogen furan-acid Med. nitrogen furan-acid Low nitrogen furan-acid Phenolic No-Bakes Phenolic-ester cured Phenolic-acid Urethanes: Alkyd-organometallic (alkyd-oil) Phenolic-amine Polyol-amine Phenolic-pyridine	Free Radical Phenolic urethane-amine Furan/peroxides-SO_2 Epoxy/SO_2 Phenolic-ester cured
Inorganic	Silicate (Warm Box)	Silicates: Sodium silicate-ester cured Sodium silicate-FeSi cured Sodium silicate-$2CaOSiO_2$ cured Cements: Cement-hydraulic cured Cement (fluid sand) - hydraulic cured Phosphates: Phosphate-oxide cured	Sodium silicate-CO_2

five times to produce moulds in some processes, after which the amount of fines becomes excessive) or disposed of when the desirable foundry sand properties have degraded to such a point that it is no longer suitable. This spent foundry sand generally makes up about 75 to 80 percent of the waste stream generated by foundries. Typically, about one tonne of foundry sand is required for each tonne of iron or steel casting produced.

The used moulding and core sands can contain several constituents picked up during the moulding and casting stages. This includes tramp metals, residual partially degraded binder, and dust generated by sand degradation during the casting stage. The tramp metals are usually recovered where practical, and the remaining spent foundry sand can be generally classified as non-hazardous, non-registrable waste based on the results of Ontario Regulation 347 Leachate Extraction Procedure test results. However, the Ontario Regulation 347 Schedule 4 leachate parameters do not include phenols concentration, which have been identified in moulding and core sands from all systems, not just those where phenolic binders have been employed.

3.0 SPENT FOUNDRY SAND GENERATORS

In recent years, several agencies have attempted to compile an inventory of spent foundry sand generators. In 1988, it was determined that the Ontario foundry industry consisted of about 75 ferrous foundries and 60 nonferrous foundries [5]. The economic conditions since 1988 have had a severe impact on the foundry industry, with increased competition from the U.S., lower demand for products due mainly to a decline in auto production, and equipment obsolescence resulting in the temporary or permanent loss of a number of ferrous, nonferrous and diecasting foundries. The most recent February 24, 1992 announcement that the General Motors foundry in St. Catharines will be closed by 1995 is indicative of the state of decline in this industrial sector in Ontario. As such, the 1988 (and even more recent) production figures are no longer appropriate for the industry, and it is necessary to look to other sources for more complete and current information.

In 1990, the University of Waterloo completed a survey of the eight members of the Canadian Foundry Group (medium to large Ontario ferrous foundries) on behalf of the Manufacturing Research Corporation of Ontario (MRCO) [6]. This work was completed to investigate the technical and economic feasibility of incorporating spent foundry sand in hot-mix asphalt concrete. While limited to only eight companies, the information obtained from these firms was quite complete and included the location and quantity of spent foundry sand generated, physical and environmental characteristics of the material from each firm, and current disposal practices. While only a portion of the Ontario foundry industry was included in this study, the eight firms involved represented about 75 percent of the total spent foundry sand produced by Ontario ferrous foundries each year.

A recent 1990/1991 survey by Aisco Systems Inc. and Canada Centre for Mineral and Energy Technology (CANMET) to establish the overall technical

and economic feasibility of setting up a centralized sand laundry system attempted to quantify the amount of spent foundry sand available and number of foundries interested in such a facility. John Emery Geotechnical Engineering Limited (JEGEL) met with Aisco Systems Inc. (P. Merlin) and CANMET (L. Whiting) to obtain information on this study, and was provided with draft results of their survey for possible use in the joint Ontario Ministry of Environment and Energy/Canadian Foundry Association (MOEE/CFA) alternative uses of spent foundry sand study. For the Aisco/CANMET study, a total of 44 ferrous and nonferrous foundries were surveyed, with a 77 percent response rate. This study is still in a draft form, and is expected to be completed in early 1992 by CANMET; however, with the relatively small number of foundries surveyed and correspondingly low response rate, it was not considered to be comprehensive enough to form the basis for this project. Nevertheless, many of the firms that did respond provided detailed information on spent sand quantities, locations, and moulding and coremaking systems that can be used to supplement and cross-reference the data obtained by a specific survey for this MOEE/CFA study.

In order to obtain the most complete and current information on Ontario spent foundry sand generators, a questionnaire was developed and circulated to all ferrous and nonferrous foundries (including diecasters) listed by the Canadian Foundry Association (both member and non-member firms). This questionnaire is reproduced as Figure 1. The response to the questionnaire was incomplete with only about 60 percent of the ferrous foundries and 40 percent of the nonferrous foundries responding, despite follow up phone calls by JEGEL staff to encourage participation. However, all major spent ferrous foundry sand producers, and a representative number of nonferrous foundries, responded. The MOEE/CFA questionnaire responses, supplemented by the recent Aisco/CANMET and MRCO surveys, provide a fairly complete overview of Ontario spent foundry sand generation in terms of the quantities and locations of spent foundry sand generated, binder systems employed and current disposal/reuse practices being used.

The spent foundry sand generators almost without exception indicated that their questionnaire responses were confidential. Therefore, the locations of spent foundry sand generators and quantities produced have been summarized in terms of the current MOEE regions and districts, with the Ontario Ministry of Transportation (MTO) regions and districts also given for comparison purposes. The current MOEE regions are shown in Figure 2, with the locations of MOEE and MTO regions and districts, and jurisdictions of municipal engineers given in Tables 2 and 3 respectively.

The approximate quantities of spent foundry sand generated per annum for each region are summarized in Table 4, with the general distribution by city shown in Figure 3.

FIGURE 1

QUESTIONNAIRE
SPENT FOUNDRY SAND ALTERNATIVE USES STUDY

Name:____________________ Company:____________________

Phone:____________ Ext.:__________ Address:____________________

Fax:____________ ____________________

If you so wish, we will keep this information in strict confidence. Please indicate, by checking the appropriate box, if this information is to be kept in confidence. Yes:____ No:____

---

1. How much spent foundry sand do you generate each year (in tonnes)?
   Moulding Sand: __________ Core Sand: __________

2. What binder system or process are you currently using for mould and core making? Please specifically indicate the organic resins being employed, if any.

3. How is your spent foundry sand currently being disposed of? If your spent foundry sand is currently going to more than one place, or being beneficially reused, please indicate the approximate amount(s) for each. If possible, please provide separate breakdowns, with costs, for moulding and core sand disposal.

4. Do you treat or screen the spent foundry sands in any way, for any particular use, before it is disposed of or reused? Please indicate the approximate costs, both capital and operating, for this treatment.

5. Please attach any recent results of physical properties testing for your spent foundry sand. In particular, we are interested in grain size characteristics, moisture content, AFS Grain Fineness Number.

6. Please attach any recent results of MOEE Regulation 347 Leachate Extraction Tests completed on your spent moulding sand and core sand. If you have any other chemical test results of interest such as phenols concentration, organic parameters or bulk analyses, these would also be greatly appreciated.

Many thanks for taking the time to complete this questionnaire. Please feel free to attach any additional comments or data, and return by fax to Michael MacKay, P.Eng. at 416-630-7045. A JEGEL representative will contact you in several days.

FIGURE 2

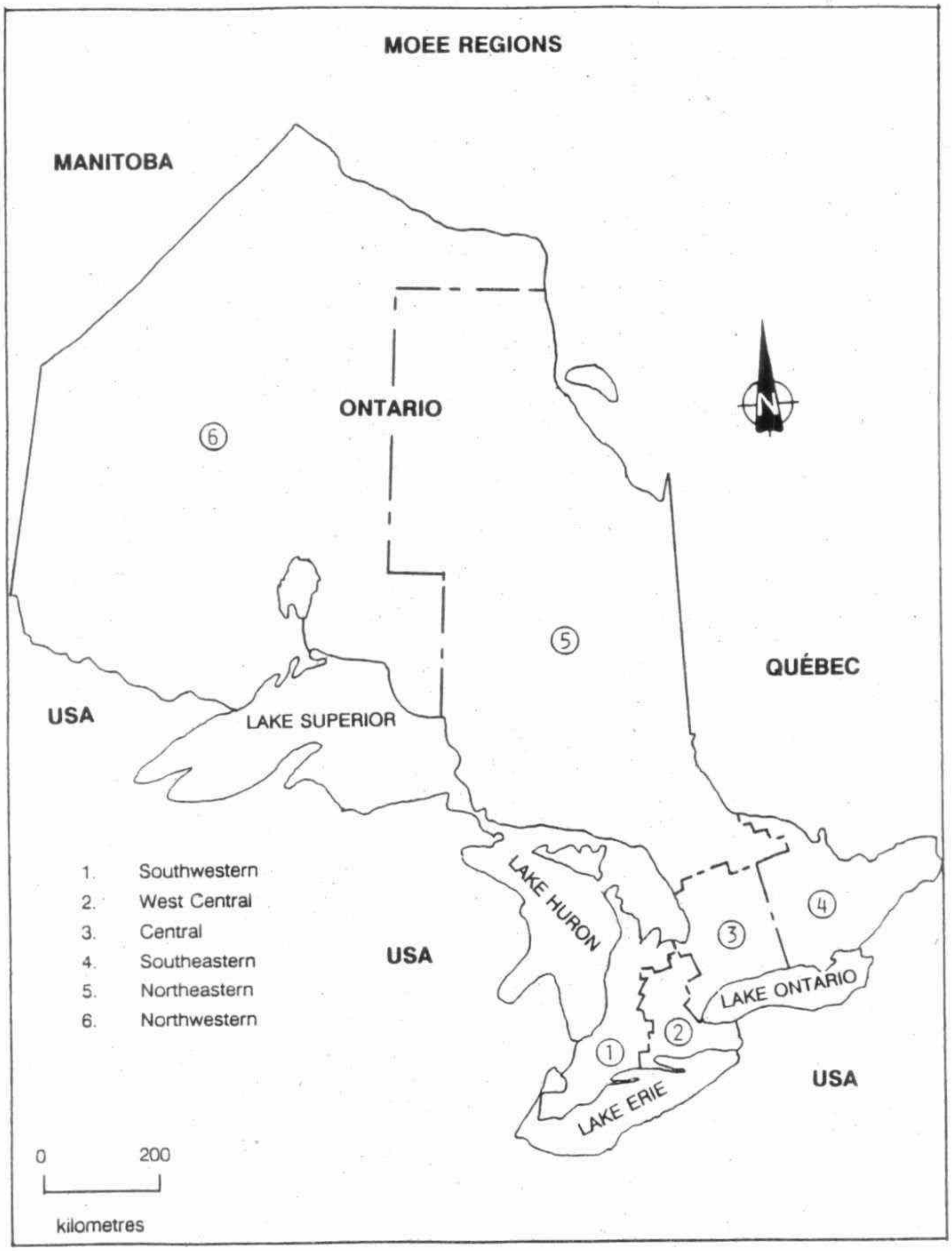

MOEE REGIONS
MANITOBA
ONTARIO
QUÉBEC
USA
LAKE SUPERIOR
LAKE HURON
LAKE ONTARIO
LAKE ERIE
USA
USA
N
6
5
4
3
2
1
1. Southwestern
2. West Central
3. Central
4. Southeastern
5. Northeastern
6. Northwestern
0
200
kilometres

TABLE 2

MINISTRY OF ENVIRONMENT AND ENERGY REGIONS, DISTRICTS
AND DISTRICT OFFICE LOCATIONS

REGIONS	DISTRICTS/COUNTIES
Southwestern Region London Regional Office Sarnia Area Office Windsor District Office Owen Sound District Office	Essex, Kent, Lambton, Elgin, Middlesex, Oxford, Perth, Huron, Bruce, Grey
West Central Region Hamilton Regional Office Cambridge District Office Hamilton District Office Welland District Office	Haldimand-Norfolk, Brant, Niagara, Waterloo, Wellington, Dufferin, Hamilton-Wentworth
Central Region Toronto Regional Office Toronto East District Office Toronto West District Office York-Durham District Office Barrie District Office Halton-Peel District Office Muskoka-Haliburton District Office Peterborough District Office	Peel, York, Durham, Peterborough, Haliburton, Victoria, Muskoka, Simcoe, Metropolitan Toronto
Southeastern Region Kingston Regional Office Kingston District Office Cornwall District Office Ottawa District Office Belleville Sub-Office Pembrooke Sub-Office	Hastings, Lennox and Addington, Frontenac, Prince Edward, Leeds and Grenville, Lanark, Prescott and Russell, Stormont, Dundas and Glengarry, Ottawa-Carleton, Renfrew
Northeastern Region Sudbury Regional Office Sudbury District Office North Bay District Office Sault Ste. Marie District Office Timmins District Office Parry Sound Sub-Office	Parry Sound, Nipissing, Sudbury, Algoma, Timiskaming, Cochrane
Northwestern Region Thunder Bay Regional Office Thunder Bay District Office Kenora District Office	Thunder Bay, Kenora, Rainy River

TABLE 3

MINISTRY OF TRANSPORTATION REGIONS, DISTRICTS
AND JURISDICTIONS OF MUNICIPAL ENGINEERS

A. REGIONS AND DISTRICTS	B. JURISDICTIONS OF MUNICIPAL ENGINEERS
REGIONS	DISTRICTS
Central Region, Toronto	Toronto
	Peel, York, Durham
Hamilton District	Toronto
Toronto District	Metropolitan Toronto Area
Port Hope District	Port Hope
	Northumberland, Victoria and southern part of Peterborough
	Hamilton
	Brant, Niagara, Hamilton-Wentworth, Halton
Eastern Region, Kingston	Kingston
	Leeds and Grenville, Prince Edward, southern parts of Frontenac Hastings, Lennox and Addington
Kingston District	
Ottawa District	Ottawa
Bancroft District	Ottawa-Carleton, Lanark, Prescott and Russell, Stormont, Dundas and Glengarry, and eastern parts of Renfrew
	Bancroft
	Northern parts of Frontenac, Hastings, Lennox and Addington and Peterborough, western part of Renfrew and six adjoining municipalities in Haliburton and Nipissing
Southwestern Region, London	Chatham
	Essex, Kent, Lambton
Chatham District	London
London District	Elgin, Middlesex, Haldimand-Norfolk, Oxford
Stratford District	Stratford
Owen Sound District	Huron, Perth, Waterloo, Wellington, Dufferin
	Owen Sound
	Bruce, Gray, Simcoe
Northern Region, North Bay	Huntsville
	Haliburton (part), District of Muskoka, and southern portion of Parry Sound
Huntsville District	
North Bay District	North Bay
New Liskeard District	Nipissing, Northern portion of Parry Sound and seven adjoining municipalities
Cochrane District	
Sudbury District	New Liskeard
	Timiskaming and Cochrane District south part and Sudbury north part
	Cochrane
	Part of Cochrane north
	Sudbury
	Sudbury, Manitoulin and small part of Algoma (east)
Northwestern Region, Thunder Bay	Sault Ste. Marie
	Algoma, and small portions of Sudbury and Thunder Bay
Sault Ste. Marie District	Thunder Bay
Thunder Bay District	Thunder Bay and Atikokan area of Rainy River District and part of Kenora
Kenora District	Kenora
	Kenora District and Rainy River

FIGURE 3

LOCATIONS OF SPENT FOUNDRY SAND GENERATORS

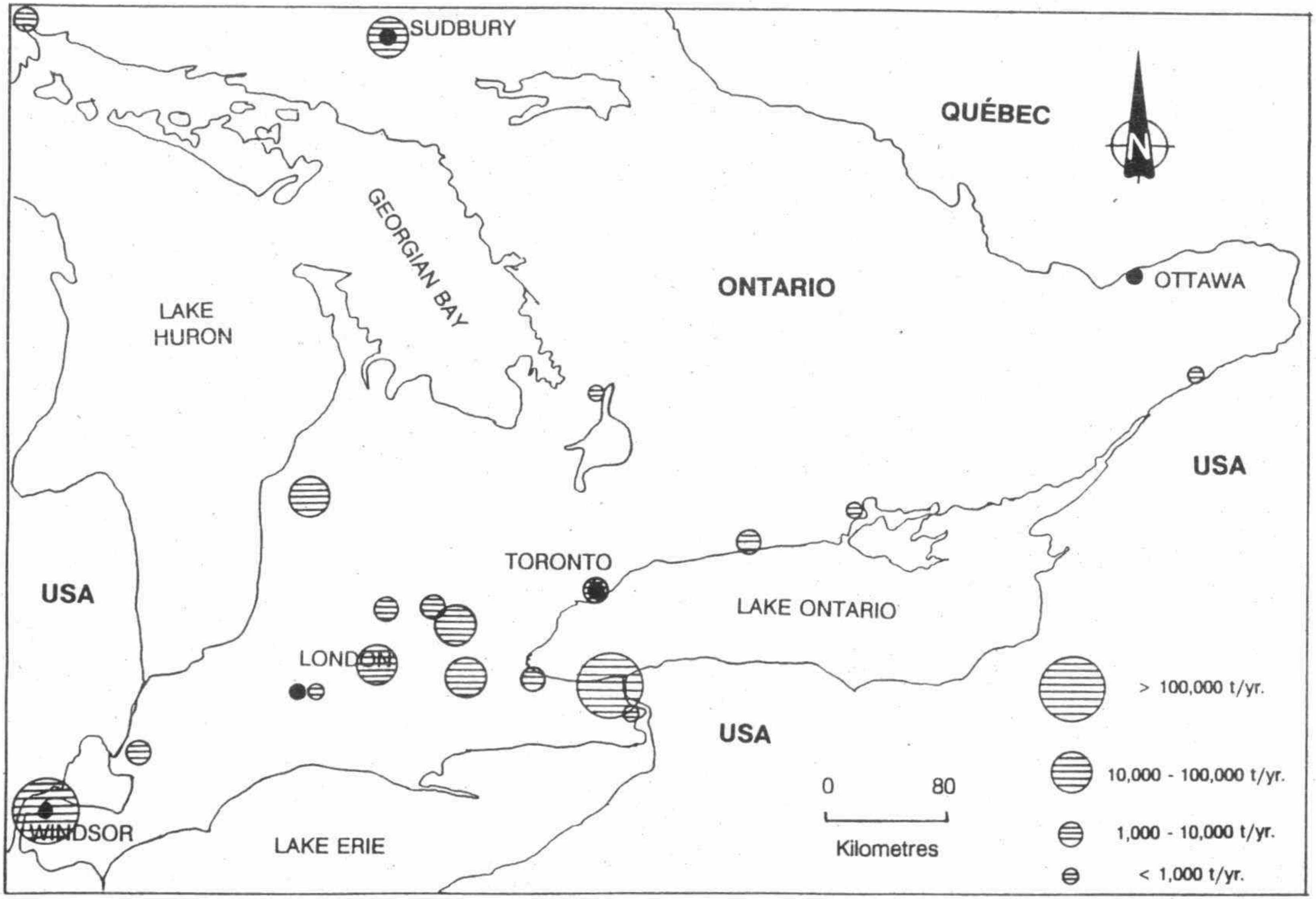


TABLE 4

SPENT FOUNDRY SAND GENERATION BY MOEE REGION

Region	Tonnes Generated Per Annum
Southwestern	178,990
West Central	177,200
Central	7,000
Southeastern	1,300
Northeastern	19,125
Northwestern	0
	TOTAL: 383,615

Responses were received from only 18 of the approximately 60 nonferrous foundries representing the province's largest producers of copper, brass and aluminum castings. The total tonnage of spent foundry sand produced by these respondents in 1991 was 4604 tonnes. As such, the total tonnage of spent foundry sand from nonferrous foundries is estimated to be about 10,000 tonnes or less, and therefore makes up only about 2 to 3 percent of the total spent foundry sand generated each year. These firms are situated entirely in the Southeastern, Central, West Central and Southwestern Regions.

4.0 SPENT FOUNDRY SAND CHARACTERIZATION

In order to determine if there are any mitigating factors that may impact on the use of spent foundry sand, it is necessary to confirm its physical and chemical characteristics. The type of spent foundry sand (ferrous or nonferrous, green or resin bonded, for instance), its physical characteristics (grain size distribution in particular, but also strength and durability properties) and its chemical composition (in terms of potentially leachable constituents such as heavy metals or the presence of phenols) may preclude the use of spent foundry sand in certain applications.

A review of the North American and International technical literature was completed as the initial phase of the characterization of spent foundry sand and to indicate current and emerging uses of spent foundry sand. This consisted of a computerized literature search through DIALOG® Information Service of technical database systems including the Metadex, TRIS, NTIS and Envirosearch databases. Abstracts of the publications of greatest interest from this literature survey are reproduced in Appendix D.

The types of spent foundry sands (and binding systems used), grain size analysis data and Ontario Regulation 347 Leachate Extraction Procedure results were provided by a number of the foundries as part of their response to the spent foundry sand questionnaire. This data, as well as previously reported data from other studies (MRCO study for Canadian Foundry Group [6] for instance), was reviewed to determine the range of physical and chemical characteristics for Ontario ferrous and nonferrous spent foundry sand for comparison with similar data reported in the technical literature.

Grain size data was received from 8 ferrous foundries and 5 nonferrous foundries. The average grain size analysis for ferrous and nonferrous spent foundry sands are given in Table 5, and the composite gradation limits are presented on Figure 4.

In addition to grain size analysis data, physical properties testing and chemical analyses (bulk analysis and leachate analysis) were completed on a typical spent foundry sand sample obtained from a CFA Foundry Sand Committee member firm (grey iron foundry - this type of foundry represents about 85 percent of ferrous foundry production). The physical tests completed were in accordance with those specified by Ontario Provincial Standard Specifications (OPSS) Form 1001 "Materials Specification For Aggregates - General" and included relative density and absorption, micro-Deval abrasion resistance, magnesium sulphate soundness loss, organic impurities and plastic limit/plasticity index completed in accordance with Ontario Ministry of Transportation (MTO) standards. The chemical analyses consisted of a bulk analysis (MOEE Upper Limits of Normal parameters [7]) and Ontario Regulation 347 Leachate Extraction Procedure (Schedule 4 Criteria, no pesticides), with standard laboratory procedures both analyses including determinations of phenols concentration. The test results are summarized in Tables 6 and 7.

During the moulding and casting processes, the foundry sands become 'contaminated' with tramp metals, residual partially degraded binder, mould additives such as seacoal, clays, organics, for instance. While generally in small quantities, these substances can have a significant effect on the environmental classification of the spent foundry sand for disposal and reuse purposes.

In Ontario, Ontario Regulation 347 defines the requirements for classification of materials for disposal purposes [8]. 'Inert fill' means earth or rock fill or waste of a similar nature that contains no

TABLE 5

GRAIN SIZE DISTRIBUTION
ONTARIO FERROUS AND NON FERROUS SPENT FOUNDRY SANDS

Sieve Size		Percent Passing Ferrous Foundries		Nonferrous Foundries	
μm	U.S. Standard Sieve Number	Average	Range	Average	Range
850	20	99.5	98.2 - 100.0	100.0	99.8 - 100.0
600	30	96.9	89.4 - 99.8	99.8	99.7 - 100.0
425	40	87.4	51.4 - 96.8	97.4	94.4 - 99.1
300	50	58.8	12.9 - 74.9	79.1	64.1 - 95.0
212	70	24.1	0.7 - 36.8	49.7	24.0 - 87.3
150	100	6.3	0.1 - 12.8	27.0	2.1 - 66.6
106	140	2.1	0 - 3.6	14.2	0 - 40.0
75	200	0.9	0 - 2.6	7.0	0 - 23.3
53	270	0.03	0 - 0.12	4.4	0 - 17.5

TABLE 6

PHYSICAL PROPERTIES TEST RESULTS
SPENT FERROUS FOUNDRY SAND

Test	Results	Specification (maximum)
Relative density, kN/m^3	2590	-
Absorption, %	0.45	1.0
Micro-Deval abrasion loss, %	1.84	25
Magnesium sulphate soundness loss, %	11.1	16
Organic impurities (NaOH colour comparison)	8	11
Plastic limit/plasticity index	Not Plastic	3

FIGURE 4

COMPOSITE GRADATION LIMITS FOR ONTARIO SPENT FOUNDRY SAND

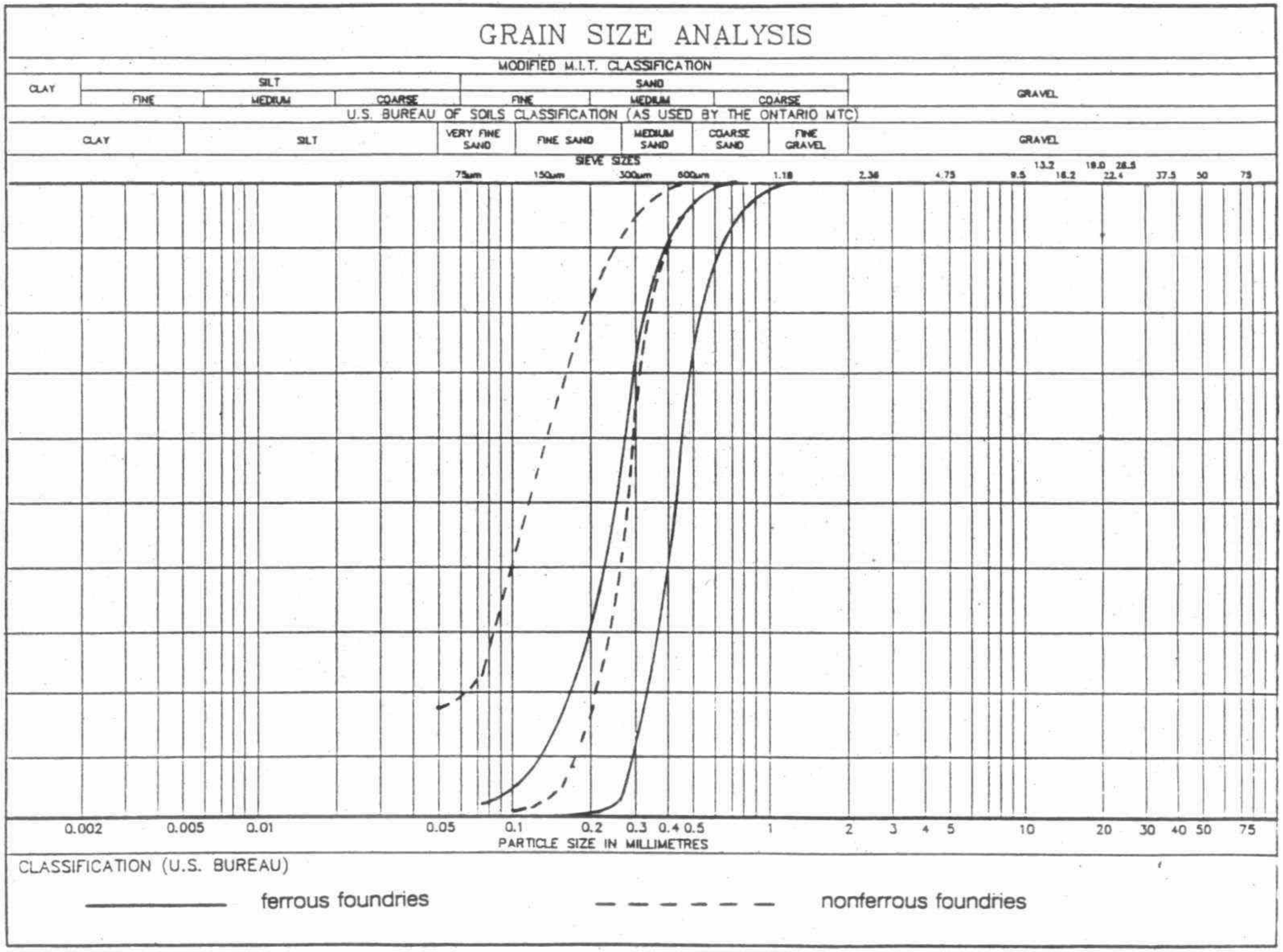


TABLE 7

TYPICAL GREY IRON FOUNDRY (GREEN SAND/PHENOLIC URETHANE)
CHEMICAL ANALYSIS RESULTS
BULK ANALYSIS AND LEACHATE ANALYSIS

Parameter	Bulk Analysis		Leachate Analysis	
	Concentration, mg/kg	Guidelines*	Concentration, mg/L	Schedule 4 mg/L
Antimony	ND**	8	-	-
Arsenic	1.0	20	ND	0.05
Barium	10.3	-	0.02	1.0
Beryllium	ND	-	-	-
Boron	-	15	ND	5.0
Cadmium	ND	4	ND	0.005
Chromium (Total)	6.3	50	ND	0.05
Chromium (VI)	1.4	-	-	-
Cobalt	ND	25	-	-
Copper	5.9	100	-	-
Cyanide (free)	-	-	0.006	0.2
Fluoride	-	-	0.28	2.4
Lead	ND	500	ND	0.05
Manganese	-	700	-	-
Mercury	ND	0.5	ND	0.001
Molybdenum	ND	3	-	-
Nickel	4.5	60	-	-
Nitrate + Nitrite	-	3	ND	10.0
Nitrite	-	60	ND	1.0
Phenols	25.7	-	0.62	-
Selenium	0.3	2	ND	0.01
Silver	ND	-	ND	0.05
Uranium	-	-	ND	0.02
Vanadium	4.7	70	-	-
Zinc	16.8	500	-	-
Total Kjeldahl Nitrogen	214	0.5	-	-
Sodium Absorption Ratio	2.44	5	-	-
Total Oil and Grease	394	1	-	-
pH	8.33	6-8	-	-

* Ontario Upper Limits of Normal Concentration in Ontario Surface Soil (Urban) [7].
** ND: Not Detected.

putrescible materials or soluble or decomposable chemical substances. Spent foundry sands are not classified as inert because of the presence of soluble materials, as determined through the Ontario Regulation 347 Leachate Extraction Procedure. The Ontario Regulation 347 Leachate Extraction Procedure is an agitated acid leachate test similar to the U.S. Environmental Protection Agency (USEPA) EP Toxicity Test (EPTox), whereby a sample of the material is placed in contact with an acetic acid solution (pH of 5.0 maintained for the 24 hour contact period) and continuously agitated (end-over-end at 10 rpm). The leachate is then filtered off and analyzed for some of the parameters listed in Schedule 4. Parameters analysed from Schedule 4 for this study are indicated in Table 8.

Wastes having leachate concentrations exceeding 100 times the Schedule 4 criteria are considered to be 'leachate toxic' and must be registered and be disposed of at an approved hazardous waste facility (such as the Laidlaw site in Sarnia) by a licensed hauler. Wastes having leachate concentrations less than 10 times the Schedule 4 criteria are 'non-registrable, non-hazardous' and require licensed haulers to transport waste to be disposed of at a conventional landfill. Wastes having leachate concentrations greater than 10 times and less than 100 times Schedule 4 criteria are 'registrable, non-hazardous' requiring generator registration and licensed haulers to transport the materials to a certified disposal site.

Ontario Regulation 347 leachate analysis data were received from a number of the foundries surveyed (12 ferrous and 5 non-ferrous foundries). The leachate test results and ranges for the data received are summarized in Table 8.

As confirmed by the leachate test results presented in Table 8, spent foundry sands from Ontario ferrous foundries are consistently well

TABLE 8

AVERAGE ONTARIO SPENT FOUNDRY SAND LEACHATE
QUALITY CRITERIA (FERROUS FOUNDRIES)
ONTARIO REGULATION 347 SCHEDULE 4 PARAMETERS
(PARTIAL LIST OF PARAMETERS INCLUDING PHENOLS)

Parameter	Concentration, mg/L Average	Range*	Concentration, mg/L
Arsenic	< 0.007	0.001 - < 0.05	0.05
Barium	0.85	0.001 - < 5.0	1.0
Boron	2.03	< 0.005 - 8.6	5.0
Cadmium	0.012	< 0.002 - 0.092**	0.005
Chromium	0.21	0.001 - 1.88**	0.05
Cyanide (free)	0.052	< 0.001 - 0.2	0.2
Fluoride	1.03	0.1 - 2.89	2.4
Lead	0.39	< 0.017 - 4.19**	0.05
Mercury	0.0005	< 0.0001 - 0.001	0.001
Nitrate + Nitrite	0.40	< 0.24 - 0.57	10.0
Nitrite	0.15	0.1 - 0.2	1.0
Selenium	0.004	< 0.001 - 0.01	0.01
Phenols	2.99	< 0.0006 - 14.2**	NA

* range, from lowest to highest, of the 12 responses received.

** the values indicated at the high end of the range are from a single foundry and not considered to be representative of typical Ontario spent foundry sand production.

within 'non-registrable, non-hazardous' limits (generally far less than 10 times Schedule 4 parameters). However, noting that the spent foundry sand from one source exhibited significantly higher heavy metals levels in the leachate than all other Ontario ferrous foundries, it is clear that spent foundry sands from specific sources must be checked and the leachate test characteristics confirmed to establish the suitability of each sand source for a particular reuse or disposal option.

The presence of phenols in spent foundry sands is not specifically addressed by the Ontario Regulation 347 requirements, or other MOEE guidelines (such as Site Decommissioning and Cleanup Guidelines [8]). Phenols are essentially considered to be an aesthetic parameter owing to the foul taste that chlorophenolic compounds impart to drinking water - leachable phenols combine with chlorinated drinking water to form chlorophenols.

Ontario Provincial Water Quality Objectives (PWQO) have been developed to maintain the quality of surface (ambient) waters for the protection of aquatic life and recreation. The PWQO criteria quoted for phenols is 1 μg/L [9]. In addition to the PWQO guidelines, Ontario has also established Drinking Water Objectives to maintain the quality of drinking water. The term 'Maximum Desirable Concentration' (MDC) is used to define the limits on substances that are either aesthetically objectionable or conflict with good water control practices. The MDC recommended for phenols in drinking water is 2 μg/L [10], which is double the PWQO guideline.

Chlorophenols are listed in the Ontario Drinking Water Quality Objectives as a substance having an 'undefined tolerance limit', a designation that is assigned to substances that may pose an adverse effect to health or the environment but for which there is insufficient scientific data to establish water quality objectives. A phenols concentration of 2000 μg/L has been reported to be toxic to fish species, with a concentration of 7,000,000 μg/L toxic to man [11].

Phenols occur naturally as part of nature's carbon cycle, with substantial quantities of phenols present in common food sources such as coffee, tea, butter, eggs, and alcohol products. Decay of vegetation such as oak leaves is a major source of naturally occurring phenols. Human and animal urine, and secretions from insects (cockroaches in

particular) are also major contributors of phenols to the environment. Domestic sewage exhibits phenol concentrations typically in the order of 70 to 100 μg/L. Phenols are readily biodegradable in nature under both aerobic and anaerobic conditions, and generally degrade very rapidly, in a matter of days, to harmless byproducts (such as carbon dioxide) [11].

Phenols in spent foundry sand are formed through high temperature thermal decomposition and rearrangement of organic binders during the pouring process. Consequently, even spent foundry sands from processes involving non-phenolic binders and additives can contain appreciable concentrations of leachable phenols. Virtually all spent foundry sands, including waste green sand, dry sand, shell sand, alkyd oil urethane sand, phenolic urethane sand, furan no-bake sand and organic-modified sodium silicates, are likely to contain traces of phenols [11].

The quantity of leachable phenols in spent foundry sand cannot be directly correlated to the type of binder used, but is related to binder addition level, composition and (more importantly) factors such as the sand-to-metal ratio (lower sand-to-metal ratio results in more complete burning of the binder during pouring), degree of cure, extent of binder thermal decomposition and rearrangement, metal pouring temperature, reclaim sand loss on ignition and cooling time between pouring and shakeout.

As the types of binder systems and casting methods vary significantly for each foundry, it is not possible to characterize the spent foundry sands (with respect to leachable phenols concentration) by process or binder system. Therefore, the phenols concentration in a given spent foundry sand can only be established by running leachate tests on representative samples from each source. However from the survey results provided by Ontario foundries, it appears that the phenol concentrations present in Ontario spent foundry sands are generally less than the Ontario Drinking Water Quality levels.

5.0 CURRENT USES OF SPENT FOUNDRY SAND

5.1 Introduction

One of the principal objectives of this Spent Foundry Sand Alternative Uses Study was to identify current spent foundry sand waste management practices in the Ontario foundry industry. In addition, the Study was also to identify alternative uses, new and emerging, for spent foundry sands in use in Ontario, elsewhere in Canada, in the United States and in other advanced countries.

It must be appreciated that these objectives overlap somewhat, noting that there are few alternative uses for spent foundry sand and these are generally straightforward and technically well-documented. The actual utilization of spend foundry sands in Ontario and elsewhere has not been fully realized, not because of lack of technical means but due largely to economic considerations. For example, virtually all alternative uses of spend foundry sand require some form of processing to ensure product consistency, and in many instance, even simple processing has in the past been found to be more costly than disposal (even when the increased value of processed spent sand is included). With the changing emphasis towards waste reduction and 3Rs, and rapidly diminishing landfill space for recyclable or reusable materials, disposal has become less viable as a foundry waste management option.

A comprehensive review of the North American and International technical literature was completed to determine current and emerging uses of spend foundry sands. For the purposes of this Study, foundry sand is not considered to be ‘spent’ until it leaves the foundry, i.e. sand reclamation and reuse within the foundry moulding operation has not been considered. Reclamation and reuse of foundry sand within the moulding operation has become a standard operation, and is routinely completed

until the sand quality (for casting purposes) has degraded to the point that it can no longer be reclaimed and reused in the foundry. Further, landfilling, including use of spent foundry sands as cover material, is not considered by MOEE to be an alternative use but rather waste disposal.

The current and emerging uses of spent foundry sand are discussed in the following sections, within the context of their specific application to a particular industry. The uses of spent foundry sand can be divided into two categories which are based on either recognition of this material's value as an aggregate or its chemical and mineralogical composition. These general categories can be listed as follows:

Aggregate Uses:

Road construction	-	granular base and subbase hot-mix asphalt fine aggregate
Concrete aggregate	-	concrete fine aggregate bricks and mortar

Chemical/Mineralogical Uses:

Cement kiln feed	-	source of silica for portland cement manufacture
Hazardous waste vitrification	-	source of silica as fluxing agent or encapsulation media

A more detailed discussion of each of the above alternative uses is presented in subsequent sections of this report.

5.2 Use of Spent Foundry Sand As Aggregates

5.2.1 General Use of Aggregates in Ontario

Before turning to the use of spent foundry sand in Ontario, it is important to recognize the overall role that conventional natural aggregates play in the Ontario economy and infrastructure. As shown in Table 9 for 1985 to 1989, the annual production of conventional aggregates (sand, gravel and stone used for construction and industrial processes) was approaching 200 million tonnes, but was probably down to about 180 million tonnes in 1990 and about 160 million tonnes in 1991 due to the slow economy. About 25 percent of the aggregates production is in the Greater Toronto Area (GTA - Metro Toronto, Halton, Peel, York and Durham Regions), while some 40 percent of aggregates consumption is in the GTA [12,13]. From Table 10, the major uses of sand, gravel and crushed stone are in roads, concrete aggregates and asphalt aggregates; some 73 percent of Ontario aggregates use is for these three applications. Ontario is the leading province in both quantity and value of structural materials production (building materials, lime, stone, sand and gravel), as summarized in Table 11 for 1988.

It is clear from the Ontario conventional aggregates production and use data, there is wide scope for reuse and recycling of waste and byproduct materials such as spent foundry sand in overall aggregates conservation. This is particularly the case in the transportation infrastructure construction and maintenance sector.

TABLE 9

ONTARIO AGGREGATES PRODUCTION*

CATEGORY/YEAR	1985	1986	1987	1988	1989	5 YEAR AVERAGE
			MILLION TONNES			
Pits and Quarries Control Act Licences**	106	128	149	154	154	138
Pits and Quarries Control Act Wayside Permits	5	6	5	5	4	5
MTO Crown Land/Private Non-designated	8	7	7	8	8	8
Crown Land	13	12	11	16	16	14
Private Land Non-designated	13	12	13	14	15	13
TOTAL	145	165	185	197	197	178

*1989 Ministry of Natural Resources Aggregate Resources Program Statistical Update.

**Pits and Quarries Control Act replaced by the Ontario Aggregate Resources Act in January 1990.

5.2.2 General Use of Aggregates in Road Construction

Uses of wastes and byproducts suitable as aggregates in road construction has been the focus of previous utilization studies [12,13], and offers the greatest potential areas for spent foundry sand use for Ontario. However, the successful utilization of wastes and byproducts to supplement conventional aggregates supply is dependent upon the consistent supply of products meeting the relevant aggregates specifications requirements for the intended use. For instance, in December 1991, MTO banned both steel slag and blast furnace slag (which had contributed approximately 550,000 tonnes of fine and coarse aggregate per annum since the late 1970s for the production of primarily Dense Friction Course (DFC) and Open Friction Course (OFC) hot-mix asphalt surfacings) from use in Ontario due to problems with random cracking and consistency.

TABLE 10

ONTARIO USE OF AGGREGATES*

TABLE 10A

ONTARIO USE OF SAND AND GRAVEL IN 1987**

USE/QUANTITY	1000 TONNES	PERCENT
Roads	50,819	52.8
Concrete Aggregate	19,231	20.0
Asphalt Aggregate	6,193	6.4
Fill	15,085	15.7
Mortar Sand	2,235	2.3
Mine Backfill	698	0.7
Railroad Ballast	284	0.3
Other Uses	1,706	1.8
TOTAL	96,251	100.0

*Less than Table 9 total as mainly Pits and Quarries Control Act sources.
**1989 Canadian Minerals Yearbook, Energy, Mines and Resources Canada (EMR, 1990).

TABLE 10B

ONTARIO USE OF STONE IN 1987*

USE/QUANTITY**	1000 TONNES	PERCENT
Crushed Stone		
Roads	31,163	50.5
Concrete Aggregate	4,581	7.4
Asphalt Aggregate	4,432	7.2
Fill	5,401	8.8
Other Uses	1,701	2.8
Total Crushed Stone	47,278	76.7
Chemical Process Stone	11,452	18.6
Pulverized Stone	712	1.2
Dimensional Stone	79	0.1
Miscellaneous Stone	2,183	3.4
TOTAL	61,704	100.00

*Ministry of Northern Development and Mines (MNDM, 1990).
**Stone sold and consumed by stone producers.

TABLE 11

ONTARIO 1988 STRUCTURAL MATERIALS PRODUCTION*

USE/PRODUCTION	OPERATIONS	QUANTITY 1000 TONNES	PERCENT OF CANADIAN TOTAL	VALUE $1000.	PERCENT OF CANADIAN TOTAL
Building Materials					
Gypsum	3	1,459		19,712	
Cement	5 plants, 16 kilns	5,533***	44.8	436,269	44.9
Clay Products	17	-		122,203	
Lime	8	1,666		114,374	
Stone**	-	58,460	47.9	313,141	48.8
Sand and Gravel**	-	104,838	36.2	336,156	39.0

*1989 Canadian Minerals Yearbook, Energy, Mines and Resources Canada (EMR, 1990).
**Less than Table 9 total as mainly Pits and Quarries Control Act sources.
***Clinker and grinding capacity about 6 million tonnes per year.

The largest use for wastes and byproducts as aggregates appears to be in transportation facilities construction and maintenance applications such as engineered fill, ballast, pipe bedding, subbase, base, shouldering and recycled cold and hot mixes (RHM)*. Ontario Provincial Standard Specifications (OPSS) for construction and materials supplemented by other standards (American Society for Testing and Materials (ASTM) for instance, and particularly Canadian Standards Association (CSA) in the case of cement and concrete) and special provisions based on local experience, are widely adopted for conventional aggregates use in pavement construction and other infrastructure work. There are currently only a few additional Ontario specifications that have been specifically developed for the reuse and recycling of wastes and byproducts as aggregates. This is undoubtedly due to users not

*See Appendix A for definitions.

unreasonably requiring wastes and byproducts used as aggregates to meet relevant standard specifications.

For the reader not familiar with road construction technology and terminology, complete descriptions of the individual pavement components, and their interrelationship, are given in Appendix B. A comprehensive listing of specifications and references for aggregate and cementitious reuse and recycling of wastes and byproducts is also given in the reference section of Appendix B. It is important that the full specifications for an intended aggregate use be checked to ensure that a waste or byproduct such as spent foundry sand is technically suitable. This will undoubtedly also require detailed characterization of the specific spent foundry sand, particularly when considering a new use. For instance, aggregate for use in subbase must meet both gradation and physical requirements such as maximum Los Angeles abrasion loss, maximum petrographic number, maximum plasticity index and minimum crushed content.

5.2.3 General Use of Aggregates in Pavements

The use of aggregates in pavements will be outlined to illustrate the general aggregates technology involved as: large amounts of conventional aggregates are used in pavement construction and maintenance (typically granular subbase, granular base, asphalt concrete surfacing); use of spent foundry sand as an aggregate in pavements has been an allowable practice in Ontario since the late 1970s and is increasing (hot mix fine aggregate); and pavement materials specifications (OPSS* across Ontario for instance) provide a wide range of practical applications guidance. Much of the information presented on the use of

*See Sections B2. and B3. of this Appendix for specification references and sources.

spent foundry sand in pavements is based on Ontario experience and the Ministry of Transportation (MTO) "Pavement Design and Rehabilitation Manual"* which JEGEL has been involved with during preparation and presentations. Emphasis will be placed on flexible (asphalt) pavements as they make up the greatest part of the road/highway network. Current or alternative uses of greatest interest or potential will be discussed in decreasing order of spent foundry sand (potential) consumption, followed by emerging alternative uses.

5.2.3.1 Granular Base and Subbase

Approximately 82 million tonnes of sand and gravel or crushed stone was used for Ontario road construction in 1987 (50.8 million tonnes of sand and gravel and 31.2 million tonnes of crushed stone from Table 9 [2]), and therefore, this would afford the greatest opportunity on a per unit volume basis for the reuse of spent foundry sand, if acceptable from an environmental approvals viewpoint. While the foundry industry has not taken advantage of this option for managing its spent foundry sand in the past, recent discussions with the MOEE Waste Management Branch suggest that spent foundry sand, if wholly used as a partial replacement of existing materials in an ongoing industry (non-waste management application), could be considered to be a 'recyclable material'. This is similar to the classification given to used asphalt or used concrete from road construction projects. On this basis, spent foundry sand could therefore be suitable for recycling in granular subbase and base. The specific environmental approvals considerations will be discussed in greater detail in Section 6 of this report.

The specific physical requirements for granular subbase (typically OPSS Granular B) and base (OPSS Granular A) are outlined in Appendix B. As spent foundry sand will obviously not meet the gradation requirements for either Granular A or B materials, it would be necessary to

proportionally blend the spent sand with a natural or manufactured (crushed) aggregate to produce a consistently in-specification product. As the gradation limits for Granular B material in particular are relatively wide, there would be no problems in achieving a suitably graded product incorporating a relatively high percentage of spent foundry sand (> 20 percent). However, given the relatively large quantity of Granular B produced per annum (upwards of about 50 million tonnes) and the comparatively small quantity of spent foundry sand available (about 380,000 t), the entire annual Ontario production of spent foundry sand could be completely used up even at very low addition levels (less than 1 percent).

In order for this type of operation to be compatible with conventional aggregates processing and for final product consistency, it would be necessary to develop a minimum stockpile of spent foundry sand at the aggregate processing plant site, which could then be blended at a consistent level with the natural aggregate. A minimum 5000 tonne stockpile of spent foundry sand, processed to crush or remove any oversized materials, cores or core butts, tramp metals and obviously undesirable materials, is recommended both for consistency and economy. The finished blend would have to be checked to ensure that it satisfies the appropriate OPSS requirements for granular subbase and base aggregates, but given the results of JEGEL testing of a typical ferrous spent sand from a grey iron foundry (Tables 5 and 6) and the technical literature, it appears that most spent foundry sand would satisfy the OPSS physical requirements for aggregates.

5.2.3.2 Hot-Mix Asphalt Fine Aggregate

With the assistance of the Ontario Hot Mix Producers Association (OHMPA) and hot-mix industry contacts, a listing of active asphalt plants was developed. This listing was then used to determine the number of hot-mix plants currently using spent foundry sand as fine aggregate.

It is estimated that approximately 13 million tonnes of hot-mix asphalt (HMA) was used in Ontario in 1990. As the fine aggregate (natural or manufactured sands, screenings, mineral filler) makes up approximately 50 percent of the mix, about 6 to 7 million tonnes of fine aggregate is required per annum to satisfy the current Ontario demand for HMA.

Of the 135 permanent asphalt plants in Ontario (the remaining 9 plants being portable plants), 24 are located in the MOEE Southwestern Region, 45 in the Central Region and 32 in the West Central Region (totalling 101 plants). The remaining plants are dispersed evenly throughout the Southeastern and Northeastern Regions (13 plants in each), with 8 plants in the Northwestern Region. Clearly, the centroid of asphalt production in Ontario coincides with the locations of major spent foundry sand generators, in the south central portion of the province.

A recent study was completed at the University of Waterloo for the Manufacturing Research Corporation of Ontario (MRCO) on behalf of the eight member Canadian Foundry Group on the use of spent foundry sand as hot-mix fine aggregate [6]. This study explored the potential benefits, which would accrue to the public, the foundry industry and the asphalt industry, of recycling spent foundry sand in hot-mix asphalt. The potential benefits included conservation of natural mineral aggregates, diversion of a recyclable material from landfills, reduced costs to the foundries, and potentially lower costs to produce quality hot-mix asphalt.

5.2.3.3 Incorporating Spent Foundry Sand In Asphalt

The use of spent foundry sand in asphalt concrete has been discussed in some detail in the aforementioned MRCO report "Feasibility Study On The Environmentally And Economically Beneficial Use Of Waste Foundry Sand In The Paving Industry" that was prepared by L. D'Alessandro, R. Haas and R. Cockfield [6], who were also retained as part of the JEGEL project team for this joint MOEE/CFA Study. As the joint MOEE/CFA

Committee considered this MRCO study to be relatively complete and current, it directed that the alternative use of spent foundry sand as a hot-mix fine aggregate only be examined in a general fashion, and only provide specific additional comments to supplement and update this previous MRCO Study.

The most significant conclusions from this MRCO Study can be summarized as follows:

1. the basic issues to be considered in the recycling of spent foundry sand as asphalt concrete fine aggregate include: a) the chemical and physical properties of the spent foundry sand, most notably its gradation; b) the quality of the particular spent foundry sand for the hot mix considered (the effects of different types of spent foundry sand on the asphalt mix properties and performance); c) continuity and consistency of spent foundry sand supply; and d) the cost of distributing the spent foundry sand including handling, processing (if necessary) and storage.

2. recycling spent foundry sand as asphalt concrete fine aggregate can have the following benefits: a) reduced disposal costs to the foundries; b) reduced demand for natural aggregates (sustainable development); c) improvement in some hot-mix asphalt properties (for instance, increased Voids Mineral Aggregate - VMA in some mixes, on a case-by-case basis); d) reduced total energy consumption; and e) diversion of this volume of material from landfills.

3. the study indicates that up to about 20 percent or more spent foundry sand can be utilized in some asphalt mixes on the basis of its gradation only (emphasis added). However, it is not likely that such high percentages of spent foundry sand will be used until enough practical experience with spent foundry sands is gained and its effect on mix properties and field performance has been established.

It should be noted that the above Study did not indicate that spent foundry sand has been used successfully as hot-mix fine aggregate in Ontario since the early 1980s, with spent foundry sands from various sources having been included in the Aggregate Sources List for MTO contracts in the MTO Burlington District for approximately the past 10 to 12 years. All aggregates used in Ontario highway construction must be approved by the MTO, and inclusion in the Aggregate Sources List confirms that the MTO accepts this material for the designated use (as asphalt

concrete fine aggregate) based on a history of satisfactory laboratory and field performance. JEGEL survey of Ontario hot mix producers indicated that only about 20,000 tonnes of spent foundry sand was incorporated in hot mix in 1991, primarily because hot mix producers did not recognize that spent foundry sand was readily available, or could readily be incorporated (with cost savings in some cases) in their hot mix products.

Primarily because of its gradation, spent foundry sand cannot be solely used to make up the hot mix fine aggregate component. The gradation range of Ontario spent foundry sands from the JEGEL foundry industry survey has been superimposed over the OPSS total fine aggregate gradation requirements for hot mix in Figure 5. It is obvious from this figure that the use of spent foundry sand in hot mix requires blending with another fine aggregate in order to satisfy the total fine aggregate gradation requirements. JEGEL experience with typical Ontario natural fine aggregates and spent foundry sand (which was also directly cited in the MRCO study report) indicates that up to about 20 percent of the natural aggregate could be replaced by typical spent foundry sand and still satisfy the OPSS total fine aggregate gradation requirements. However, there are other mitigating factors that preclude using spent foundry sand at this level.

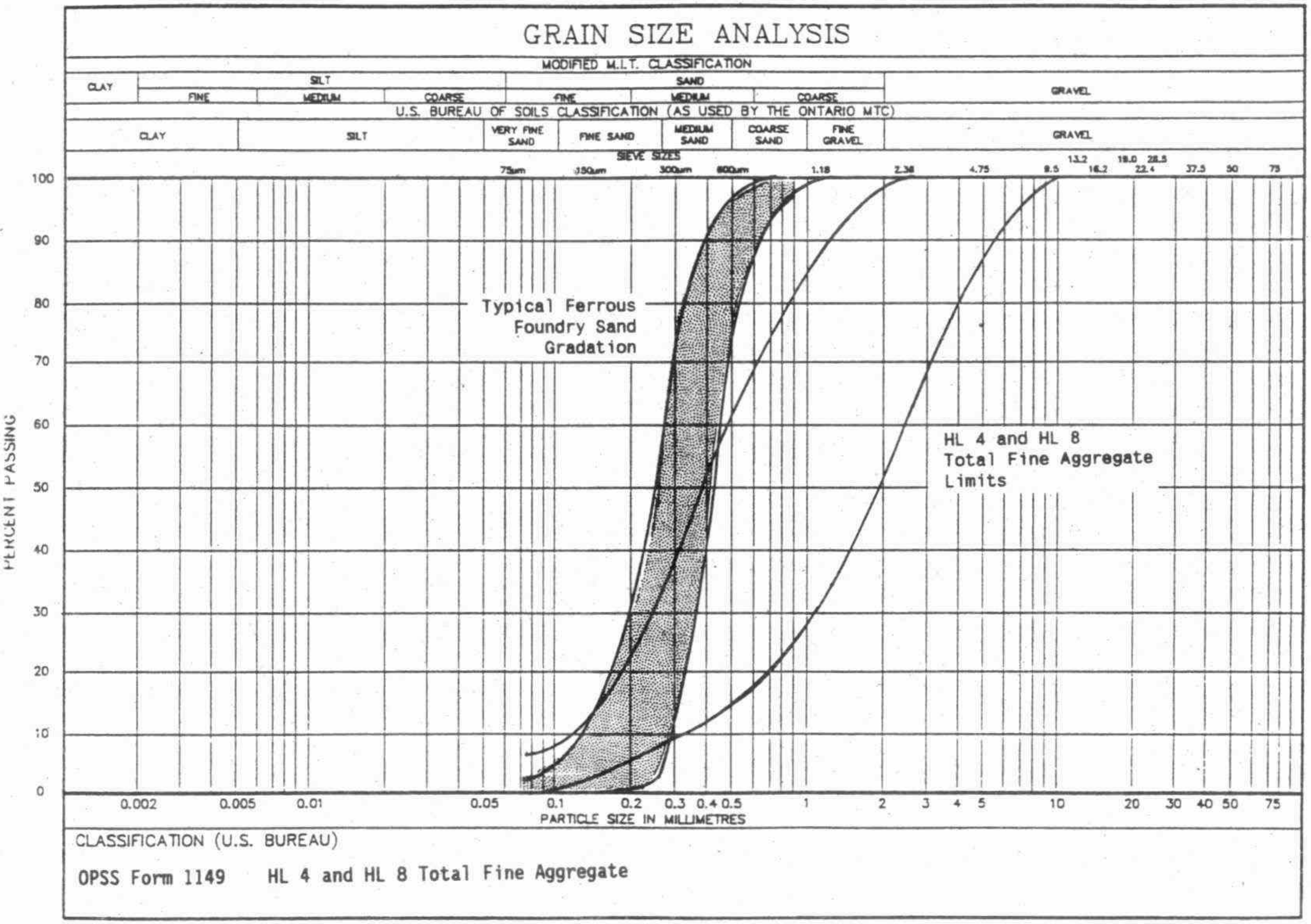
A desirable feature of asphalt concrete (see appendix for definitions) is that it must be durable in the presence of moisture. It is often incorrectly assumed that asphalt concrete is impermeable due to the presence of the bituminous binder, and the general tight appearance of an asphalt concrete surface. However, most pavements are somewhat permeable, and are by their very use, placed in areas where they come in direct contact with water (precipitation or surface runoff). Consequently, it is imperative that the asphalt cement film that coats the individual aggregate grains and binds the mixture together remains intact in the presence of water.

Spent foundry sand is largely composed of silica sand, coated with a relatively thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust. By nature of its chemical composition and mineralogy, silica sand is hydrophillic, meaning that it has an affinity for water (attracts water to its surface). This property can result in 'stripping' of the asphalt cement coating surrounding the aggregate grains with resulting loss of fine aggregate from the pavement and rapid progressive deterioration.

In order to determine the impact of such stripping potential on the performance of asphalt mixes incorporating spent foundry sand (or other siliceous natural aggregates including trap rock, granite, dolomitic sandstone, quartzite), it is necessary to complete moisture accelerated damage tests in the laboratory as part of the overall mix design. Several tests are available, with the 'standard' test in Ontario being the Immersion Marshall test which compares the stability and visual appearance of laboratory prepared briquettes before and after immersion in a heated (60°C) water bath. Stripping resistance can be enhanced through the addition of an anti-stripping additive such as hydrated lime or proprietary product as listed on the MTO Designated Sources List for Asphalt Anti-Stripping Additives (DSM # 3.05.10). Use of such additives obviously adds to the cost of producing the hot mix.

The presence of relatively high amounts of dust, or thick coatings of burnt carbon, binders and mould additives can also affect the ability of the asphalt cement binder to coat the aggregate grains. While, in general, most Ontario spent foundry sands from ferrous foundries are suitable after processing to remove any oversized or obviously objectionable material (broken cores, core butts and pieces of metal, plus any 'fugitive' materials such as gloves and refuse), the performance of specific spent foundry sands in hot mix must be evaluated on a source-by-source basis.

FIGURE 5



JEGEL

Direct JEGEL experience in the design and evaluation of hot mix incorporating spent foundry sand over the past 15 years or so indicates that a maximum of 15 percent clean spent foundry sand can be practically added to hot mix. Where the spent foundry sand addition level exceeds this amount without the addition of an anti-stripping additive, observed problems include fine aggregate loss and pavement deterioration very shortly after construction.

The method of incorporating spent foundry sand into hot mix varies from plant to plant, and depends on the plant type, its aggregate handling (drying) capabilities, and spent sand condition (moisture condition in particular). Hot mix plants currently using spent foundry sand have adopted one of two basic approaches. Where the spent foundry sand has been processed and stockpiled outdoors (similar to conventional aggregates), it has retained moisture which must be removed during hot mix production. This requires that the spent foundry sand be added to the mix and dried along with the conventional aggregates, i.e. conventional cold feed from open storage bins to the aggregate dryer. The presence of bentonite and organic materials in the spent foundry sand could result in somewhat increased time required for proper drying, and increased load on the hot-mix plant dust collection system (baghouse). However, on the positive side, the aggregate dryer temperatures and pressures typically involved are adequate to combust any remaining sea coal and organic binders, resulting in an overall 'cleaner' sand. Most Ontario hot mix suppliers currently adding spent foundry sand to their hot mix are using this system.

Alternatively, the spent foundry sand can be metered directly into the pugmill (batch plants only) or through the Reclaimed Asphalt Pavement (RAP) feed (drum plants) where it is dried by the already heated conventional aggregates. If added directly to the pugmill, the spent foundry sand must be relatively dry, and only a relatively small amount of spent sand can be properly handled (< 5 percent) unless the conventional aggregates are superheated (greatly increases the overall energy cost of hot mix production and is therefore usually not

practical). We are aware of only one Ontario hot mix supplier that adds spent foundry sand in this fashion - at Capital Paving Limited plant in Guelph, the MOEE provided a $ 19,600 grant in 1988-89 under the Industrial Waste Diversion Program to assist in the construction of a building to store dry spent sand received directly from the foundry and installation of a conveying system to allow the spent sand to be added at a relatively low level (~ 6 percent) via the RAP feed conveyor.

The major concerns of the hot mix industry in using spent foundry sand are product consistency and adequate supply. The characteristics of the spent foundry sand (gradation especially) must be relatively consistent so that once a proper mix design has been completed to establish the individual aggregate proportions and the plant has been properly calibrated, a consistent hot mix product results. Variations in the characteristics of the spent sand will result in variations in the final product, with the hot mix supplier responsible for any out-of-specification material and ensuing penalties. Further, the hot mix producer designs his products (and establishes their prices) annually based on his aggregate supplies, with substantial additional costs involved in new mix designs and purchase of alternative aggregates if the supply of spent foundry sand changes part way through the construction season. This has been a major concern of at least one hot mix producer who, on two separate occasions after completing mix designs and committing to supply substantial quantities of hot mix at prices which reflected a lower cost due to incorporating spent sand, found his spent foundry sand supply disappear when the foundries closed midway through the construction season.

Conventional hot mix fine aggregate currently ranges in price from $ 11 to $ 12 per tonne in Ontario, depending on the aggregate type and availability, plant location, and other factors. Where spent foundry sand is currently being used in hot mix, it is apparently being supplied free of charge or at relatively low rates (by waste management companies

who typically charge the foundries about $ 20 to $ 25 per tonne F.O.B. the foundry to handle their spent sand, then look to divert this type of material from landfills to reduce their disposal costs), or the hot mix plants are charging a tipping fee of about $ 6 per tonne for clean sand (a relatively low cost designed to recover the cost of any capital equipment purchases such as plant modifications and buildings associated with using spent foundry sand).

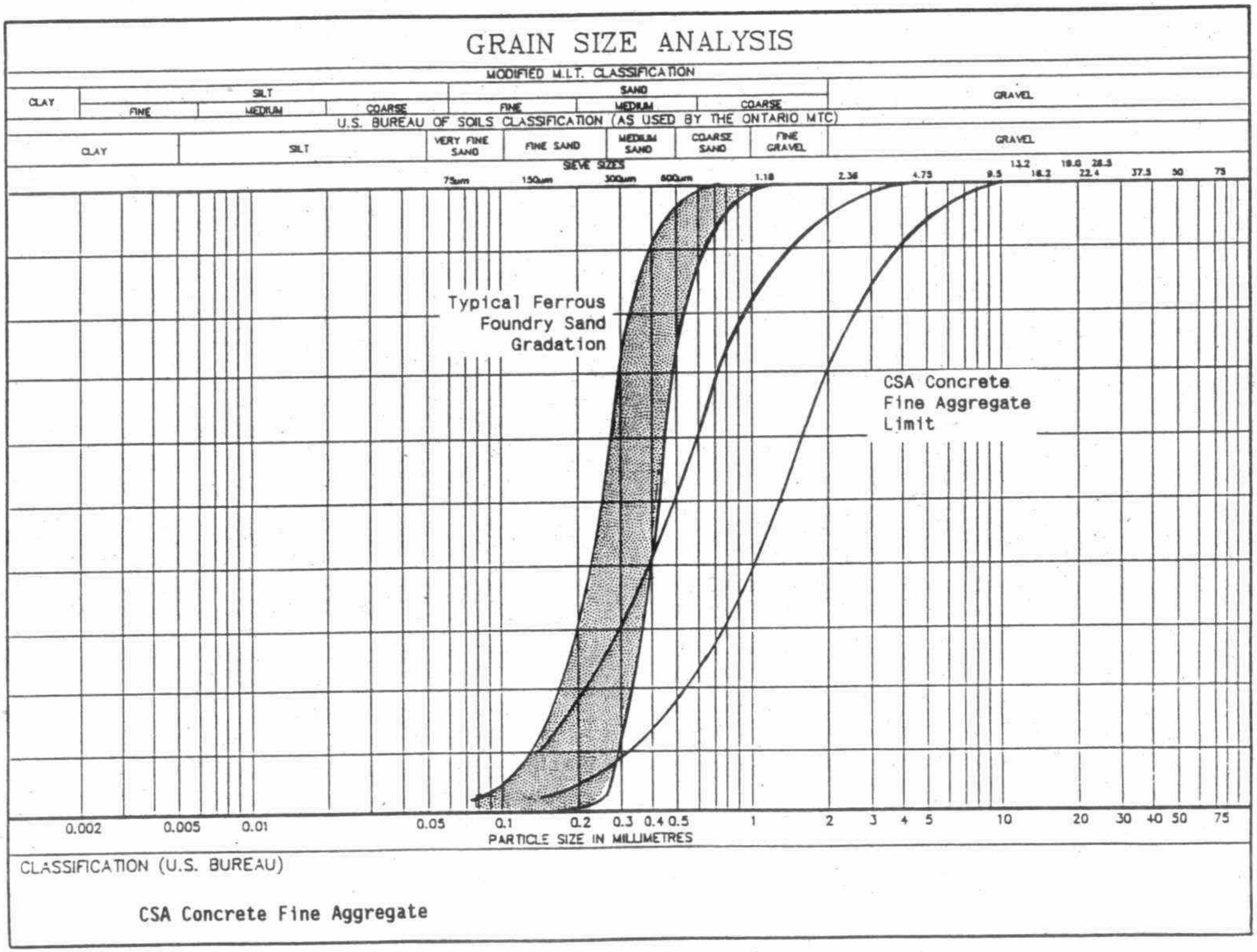
5.2.4 Concrete Aggregate

Aggregates suitable for use in concrete must conform to the requirements of Canadian Standards Association CAN/CSA-A23.1-M90 and satisfy the physical and chemical requirements specified therein. These include gradation, soundness (magnesium sulphate), organics content, and presence of deleterious materials such as clay lumps and low density granular material. Virtually all concrete products, including ready mix portland cement concrete, precast concrete, concrete block and pipe, interlocking paving stones (pavers) and modular block retaining wall systems, specify the use of fine aggregates conforming to CSA requirements.

5.2.4.1 Concrete Fine Aggregate

The average Ontario spent foundry sand gradation is superimposed over the concrete fine aggregate gradation requirements in Figure 6. Clearly, the spent foundry sand does not comply with the gradation requirements, being too fine. Similar to the previous discussions on the use of spent foundry sand as asphalt concrete fine aggregate, the spent foundry sand could be blended with a suitable natural or manufactured sand to meet the total concrete fine aggregate gradation requirements.

FIGURE 6



JEGEL

JEGEL characterization of a typical grey iron spent foundry sand (Table 4) indicated that the particular spent foundry sand satisfied CSA requirements for organic impurities and magnesium sulphate soundness, as well as MTO requirements for plasticity index and micro-Deval abrasion resistance. In addition, mortar cubes were cast in the JEGEL laboratory for comparison with a conventional natural concrete fine aggregate. Although slightly darker in colour from the conventional mortar, the spent foundry sand mortar exhibited similar setting and compressive strength characteristics to conventional concrete sand mortar.

It appears that some spent foundry sands may be suitable for use as concrete aggregate, noting that it would be necessary to completely characterize specific spent sand sources, particularly organics content and its associated potentially reduced strength. The somewhat darker colour is also considered to be an impediment to its general use as concrete fine aggregate, however it might still be practical for use in unexposed or buried concrete, or in concrete products where colour is not a concern. For example, a large interlocking concrete paver manufacturer in the GTA has expressed an interest in utilizing suitable spent foundry sand as a partial replacement for conventional concrete fine aggregate (this single manufacturer currently purchases about 200,000 tonnes of concrete fine aggregate each year). Precast concrete pavers must meet CSA CAN3-A231.2-M85 requirements [15].

Other concrete products where byproduct materials such as spent foundry sand could be considered include precast concrete storm sewer pipe, modular slope block components (same technology as interlocking concrete pavers) and precast patio stones. For any of these uses, spent foundry sand must meet the CSA requirements for concrete fine aggregate.

Suitable spent foundry sand could also be considered for use as a partial replacement for concrete fine aggregate in unshrinkable fill (see

Pg B-7 for definitions), a relatively low strength, high slump concrete product used since about 1984 to backfill utility cuts and trenches in the Metro Toronto area. As one of the principal features of unshrinkable fill is its ability to be re-excavated at a later date, strength properties of the mix are not as critical as for conventional concrete.

5.2.4.2 Bricks and Mortar

The manufacture of cement-based bricks and mortar requires the addition of fine sand similar in gradation and physical characteristics to that used in the foundry industry. The most important elements in the end product are strength, durability and colour, with clay brick products the basis for comparison. Therefore, the fine sand substitute must not impart any characteristics which result in degradation of strength or durability (such as the presence of potentially deleterious organic materials, which must be checked by completing strength comparison tests in accordance with CSA requirements) or causes a discoloration of the end product. While clay bricks are the predominant product in the Ontario construction industry, cement-based moulded bricks and calcium silicate brick and masonry products make up about 20 to 30 percent of the Ontario brick industry due primarily to their lower cost. Calcium silicate bricks are produced using either hydrated lime or quicklime and sand, which are blended then autoclaved to form hydrated calcium silicates similar to those created when water and portland cement are mixed. Similarly, there are several processes for manufacturing moulded bricks using portland cement binder and natural aggregates (interlocking concrete block pavers, for instance) or aggregates consisting of inorganic solid wastes and byproducts such as spent foundry sand, fly ash and ground glass [16]. A new process has been recently introduced that apparently blends waste materials such as recycled plastic containers, fly ash, waste tire rubber and old brake linings to produce a black interlocking paver unit (this product is currently being researched and

is not currently available to our knowledge).

The use of spent foundry sand to produce pavers and precast concrete products was discussed in some detail in the previous Section 5.2.4.1. The major discriminating factor against the use of spent foundry sands in these products appears to be the resulting dark colour, noting that bricks and paver units are preferred primarily for their aesthetic properties. Calcium silicate concrete products similarly can be sensitive to colour.

5.3 Uses of Spent Foundry Sand In Chemical/Mineralogical Processes

5.3.1 Cement Kiln Feed

Portland cement is produced by high temperature firing of calcareous material such as limestone or dolomite with silica and alumina, with some iron oxide as a fluxing agent. The resulting 'clinker' consisting essentially of hydraulic calcium silicates ($3CaO \bullet SiO_2$, $2CaO \bullet SiO_2$) and aluminates ($3CaO \bullet Al_2O_3$, $4CaO \bullet Al_2O_3 \bullet FeO$) to which calcium sulphate (in the form of gypsum) has been added as a set control agent (4 to 5 percent by mass). Materials used to manufacture portland cement must have the appropriate proportions of lime, iron, silica and alumina, and while the major constituents are largely provided by natural rock materials such as limestone, dolomite and shale, as many as 50 percent of all industrial byproducts probably have potential as raw materials for cement manufacture. A partial list of the most common sources of raw materials used in the manufacture of portland cement are given in Table 12 [from 14]. As kiln systems and the bulk constituents of the raw materials vary from plant to plant, each facility must be considered individually, with the plant chemist usually responsible for determining the specific raw materials requirements at his plant. For the reader not familiar with the terminology and general steps involved in cement manufacture, Appendix C presents a brief overview.

TABLE 12

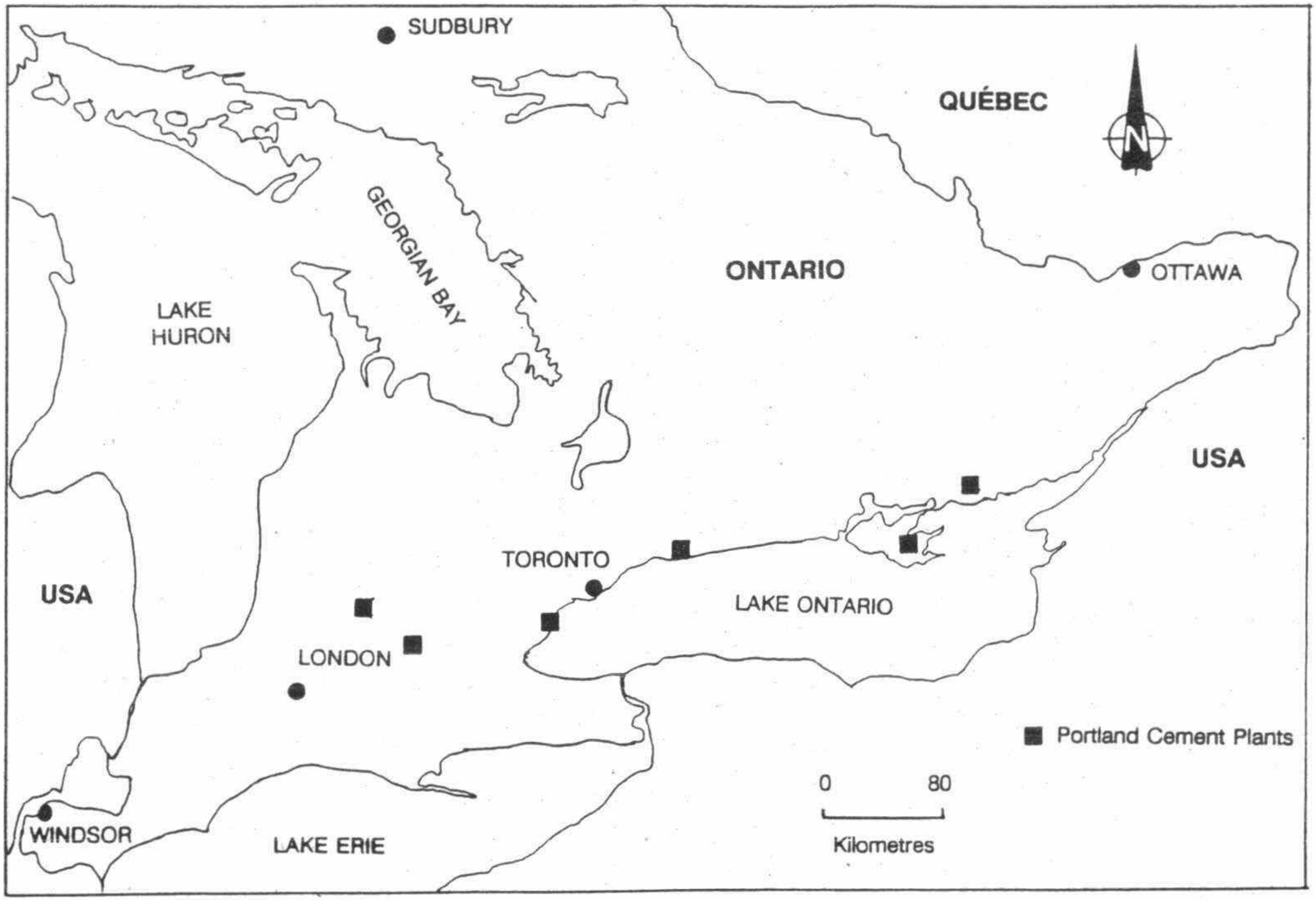
SOURCES OF RAW MATERIALS USED IN THE MANUFACTURE OF PORTLAND CEMENT [14]

Lime, CaO	Iron, Fe_2O_3	Silica, SiO_2	Alumina, Al_2O_3	Gypsum, $CaSO_4 \cdot 2H_2O$	Magnesia, MgO
Alkali waste	Blast furnace flue dust	Calcium silicate	Aluminium ore refuse	Anhydrite	Cement rock
Calcite	Clay	Cement rock	Bauxite	Calcium sulphate	Limestone
Cement rock	Iron ore	Clay	Cement rock	Gypsum	Slag
Chalk	Mill scale	Fly ash	Clay		
Clay	Ore washings	Fuller's earth	Copper slag		
Fuller's earth	Pyrite cinders	Limestone	Fly ash		
Limestone	Shale	Loess	Fuller's earth		
Marble		Marl	Granodiorite		
Marl		Ore washings	Limestone		
Seashells		Quartzite	Loess		
Shale		Rice hull ash	Ore washings		
Slag		Sand	Shale		
		Sandstone	Slag		
		Shale	Staurolite		
		Slag			
		Trap rock			

There are currently 6 portland cement manufacturing plants in Ontario, as indicated in Figure 7. Annual production of portland cement in Ontario averaged about 4.6 million tonnes for the years 1985 through 1987 [12], although with the current recession, production has probably dropped close to the 1982 level of about 3.5 million tonnes.

The use of spent foundry sand as cement kiln feed has been ongoing since about the mid 1970s. Work by The Peerless Cement Company in Detroit, Michigan demonstrating that spent foundry sand could be used as cement kiln feed prompted interest in Southern Ontario in about 1977, with at least one of the five Ontario manufacturers actually undertaking to use spent foundry sand from the Hamilton area, and another conducting trials. Despite this positive initial interest in the use of spent foundry sand, it does not appear to have become very widespread.

FIGURE 7
LOCATIONS OF ONTARIO PORTLAND CEMENT MANUFACTURING PLANTS



Review of the recent American Foundrymen's Society (AFS) sponsored study on alternate uses of spent foundry sand [3] and subsequent personnel communication with the Construction Technology Laboratories, Inc. (CTL, associated with the Portland Cement Association) suggests that only limited research on the use of spent foundry sand as cement kiln feed is in the public record, with most work apparently completed in-house by the cement manufacturer internal laboratories. The CTL testing reported in the AFS study indicated that portland cement manufactured using spent foundry sand (up to 13.4 percent) exhibited slightly higher compressive strengths than conventionally produced portland cement, with no detrimental effects on key portland cement characteristics such as set time. Phase II of the AFS study is to include a demonstration project (plant scale) on the use of spent sand as kiln feed.

Despite this apparent lack of technical documentation, it has been confirmed that one Ontario cement plant used approximately 6000 tonnes of processed spent foundry sand during 1991 in the manufacture of Type 20 (Low Heat of Hydration) portland cement, and would have used more except that its supplier did not have an adequate supply of material. This same company is proposing to completely replace the shale addition with spent foundry sand (adding both silica and iron oxide to the clinker) in 1992 in its total production, requiring up to about 36,000 tonnes of spent sand.

Based on an addition level of about 5 percent of the raw materials required to produce portland cement, the Ontario cement industry has the capacity to use about 200,000 tonnes of spent foundry sand. However, it should be noted that most of the Ontario cement manufacturers have current, well-established raw materials sources of supply, often involving byproducts that would essentially compete with spent foundry sand in this area. Table 12 confirms that there is a relatively wide list of industrial byproducts and natural materials that could be

considered as cement kiln feed, and one major Ontario portland cement manufacturer has made a reported 20 year commitment to use fly ash from Ontario Hydro as a supplementary silica source. Therefore, the viability of using spent foundry sand as cement kiln feed will be largely governed by economic factors, i.e. the ability of spent foundry sand to compete from a cost viewpoint with established silica supply sources.

5.3.2 Mineral Wool Products

Mineral wool products typically consist of one of three types: rock wool, slag wool or glass fibre. All products involve similar manufacturing processes but different raw materials.

Rock wool is produced from a melt containing basalt or diabase rock, a limestone or dolomite flux, and coke as fuel. Slag wool is manufactured using blast furnace slag, while glass fibre is produced using high grade silica sand or quartzite.

The wool products are typically formed by melting the appropriate ingredients in a cupola furnace which is then fed to a multiple disc spinner where fibres are formed through centrifugal action, or by passing the melt through a slotted openings in a bushing then fiberizing the resulting jet with steam [12]. Depending on the process involved and the composition of the raw materials, it may be necessary to add supplementary silica and alumina to obtain the desired composition. The correct proportion of silica and alumina must be maintained in order for the material to be melted and fiberized. As mineral wool products typically do not require the same high end-product quality standards as other glass products (glass, optical fibres, glass fibre), spent foundry sands could be considered as a high grade silica or supplementary silica source, with spent foundry sands from investment casting processes suitable as a supplementary source of alumina.

A U.S. rock wool producer, Fibrex in Illinois, uses scrap silica and alumina in its process [3]. However, for spent foundry sand to be used, it must be briquetted in about 25 mm diameter by 75 mm cylinders to prevent the sand particles from being blown up the cupola stack, or introduced through a preheater. While positive results were obtained in bench scale trials at Fibrex and another rock wool manufacturer and full scale trials are proposed, this is not considered to be a high potential alternative use of Ontario spent foundry sand given the additional costs involved in briquetting and the currently limited manufacturing capacity by this process.

5.3.3 Hazardous Waste Vitrification and Stabilization

Considered to be somewhat of an emerging technology for utilization of spent foundry sand, the need for silica, either as a fluxing agent for treatment of mining and smelting wastes containing heavy metals (conventional metals recovery technology) or as an encapsulating medium for particles of contaminated material (emerging hazardous waste treatment technology), could provide an area where spent foundry sand could be consumed, (particularly leachate toxic 'hazardous' spent sand from nonferrous foundries).

Noranda Sales Corporation Ltd., Recycling Department (a division of Noranda Minerals Inc.) contacted JEGEL to outline their process for treating mining and smelting wastes at their Kidd Creek and Falconbridge facilities. The smelting process involved in the recovery of precious metals (gold, silver, platinum for instance) requires silica as a flux to convert elemental metals (primarily lead and copper) in the tailings to insoluble metal silicates prior to tailings disposal. Siliceous mine waste rock and rock flour, silica sand, printed circuit boards and baghouse dusts can be used a sources of silica, and Noranda has expressed an interest in accepting spent foundry sand as a service to the foundry

industry. Noranda is apparently currently accepting USEPA hazardous spent sand from nonferrous (copper and bronze) foundries in the United States, and was investigating the market in Ontario.

Abco Recycling in Brantford and Ingot Metal Company, Ltd. are also working on Noranda's behalf, and indicated that the Kidd Creek smelter had the capacity to use about 2000 tonnes per month (about 24,000 tonnes per annum) of spent foundry sand. Noranda indicated that a tipping fee of about $ 60 F.O.B. the Kidd Creek smelter was being considered to handle this material. Given the current rates for land disposal of non-registrable, non-hazardous and registrable, non-hazardous spent foundry sand, the current alternative uses for such material and the transportation costs involved to Kidd Creek, this alternative would only appear to be viable for leachate toxic (hazardous) spent foundry sand from a few nonferrous foundries.

Hazardous waste vitrification is an emerging hazardous waste treatment technology whereby the glass acts as an electrolyte allowing some metals to be extracted from the glass and other contaminant particles are encapsulated by a silicate shell. This Vitrification and Environmental Recycling Technology (VERT) has not, to our knowledge, been tried in Ontario, and is also considered to be unproven by the USEPA. This technology is an extension of traditional glass making activities [17], where glass or glass slag products can be produced by melting and fusion of the silica followed by rapid cooling into a solid glass form. The VERT process is completed at an existing glass making factory that had since been closed, however, smaller scale units for commercial treatment of contaminated materials are in the development stage in the U.S. (Rostoker, Inc. in Illinois, Envitco in Ohio and Pennberthy Electromelt in Seattle, Washington are three such systems [3]). The Rostoker, Inc. process is used for treating electroplating sludge high in heavy metals, with silica and soda ash melted in a cupola furnace either

to convert metal hydroxides to ingot which can be reclaimed if economical, or to metal oxides retained in chemical solution in the silicate matrix of the slag. The slag is apparently suitable for reuse as road aggregate in the U.S.A.

6.0 ENVIRONMENTAL APPROVALS CONSIDERATIONS

The Ontario environmental regulations and guidelines affecting the use of byproduct materials are somewhat complicated, particularly for the layperson, and are covered in several existing documents and legislation. The Environmental Protection Act [18] defines the responsibilities of individuals and agencies for protecting and preserving the natural environment (air, water and soil), with Part V outlining the responsibilities of waste generators and waste management system operators. It outlines fundamental parameters including ownership of wastes, and the laws governing disposition and management of wastes and waste sites, and clearly assigns the responsibility for identification and proper disposal of wastes on the generator.

The principal document covering the classification and registration of waste is Ontario Regulation 347 [8]. Ontario Regulation 347 provides the definitions for the various categories of waste, waste generators and facilities, and waste handling requirements, and provides limits and procedures for testing to determine the classification of a waste material.

Ontario Regulation 347 does not distinguish between wastes and byproducts. All products or byproducts from waste transfer, bulking, treatment or processing facilities are considered to be 'waste'. Waste materials that are being reused, reclaimed or recycled are nevertheless still considered to be waste but may be exempt from regulation.

In order to determine the characteristics of a waste material for disposal purposes, its waste classification must be determined. The Leachate Extraction Procedure (LEP) is only one method of hazardous waste assessment. The LEP is an agitated acid leachate extraction test that consists of contacting a sample of waste material with a liquid to

determine which components of the waste will dissolve. The premise adopted in requiring acid leaching is that the material, when placed in a conventional landfill, could come into contact with acidic water, and in doing so, certain compounds and elements could be leached from the waste. Acid leachate tests have been developed to simulate the worst exposure conditions that a waste might be subjected to in actual sanitary landfill conditions (pH typically in the order of 5, which is much more acidic (more severe) than is encountered under conventional exposure conditions). Other agencies use tests similar to the Ontario LEP; for example, the USEPA Toxicity Characteristics Leaching Procedure (TCLP) and Quebec Ministry of the Environment (MENVIQ) Procedure for Assessing the Characteristics of Solid Wastes and Pumpable Sludges (Q.R.s.Q.) are similar agitated acid leachate extraction tests, with all three tests apparently evolving from the former USEPA Extraction Procedure Toxicity Test (EPTox) that was proposed in about 1980.

In the LEP, 50 g of the waste material are placed in 800 mL of distilled water. Acetic acid (0.5 N) is then added to lower the pH of the leachant to 5.0 ± 0.2. The sample and leachant are tumbled at 10 rpm for 24 hours, during which time the pH is monitored and maintained at 5.0 ± 0.2. The volume is brought up to a 1000 mL standard, then the leachate is filtered and tested for 15 parameters (plus 15 organic compounds, primarily pesticides) as listed under Leachate Quality Criteria, Schedule 4 in Ontario Regulation 347, and given in Table 13.

As defined by Ontario Regulation 347, one of the classification of waste materials for disposal purposes is based on the concentration of parameters in the waste material as compared with the LEP Schedule 4 criteria as described in Table 14.

TABLE 13

LEACHATE QUALITY CRITERIA
ONTARIO REGULATION 347 SCHEDULE 4
(EXCLUDING PESTICIDES)

Parameter	Concentration, mg/L
Arsenic	0.05
Barium	1.0
Boron	5.0
Cadmium	0.005
Chromium	0.05
Cyanide (free)	0.2
Fluoride	2.4
Lead	0.05
Mercury	0.001
Nitrate + Nitrite	10.0
Nitrite	1.0
PCB	0.003
Selenium	0.01
Silver	0.05
Uranium	0.02

TABLE 14

ONTARIO WASTE CLASSIFICATION

Leachate Concentration Compared To Schedule 4 Parameters	Waste Classification
< 10 times	non-registrable, non-hazardous
10 to 100 times	registrable, non-hazardous
> 100 times	leachate toxic (hazardous)

The disposal of non-registrable, non-hazardous wastes (< 10 times Schedule 4 leachate concentration parameters) can be conducted at a conventional landfill without generator registration or completion of a manifest. However, a certified (licensed) hauler and a certified (licensed) receiver is required.

Registrable, non-hazardous wastes (10 to 100 times Schedule 4 leachate concentration parameters) may be disposed of at a conventional landfill without completion of a manifest. However, generator registration, a certified hauler and a certified receiver is required.

Leachate toxic waste (hazardous waste, > 100 times Schedule 4 leachate concentration parameters) must be disposed of at a certified landfill with generator registration, completion of a manifest, using a certified hauler and a certified receiver (such as the Laidlaw facility near Sarnia).

The following Table 15 summarizes the above discussion:

TABLE 15
LEACHATE CONCENTRATION COMPARED TO SCHEDULE 4 PARAMETERS

Disposal Requirements	Leachate Concentration Compared to Schedule 4 Parameters < 10 times	10 - 100 times	> 100 times
Generator Registration	No	Yes	Yes
Manifest	No	No	Yes
Certified Hauler	Yes	Yes	Yes
Certified Receiver	Yes	Yes	Yes
Conventional Landfill	Yes	Yes	No

Most hazardous wastes come under the Ontario Dangerous Goods Transportation Act, which pertains to the transportation of dangerous goods including waste within the province using roads. The transportation of dangerous goods in Canada is under the jurisdiction of the federal Transportation of Dangerous Goods Act and Regulations.

There are two key definitions given in Ontario Regulation 347 that are of particular interest to spent foundry sand generators. 'Inert fill' is defined as "earth or rock fill or waste of a similar nature that contains no putrescible materials or soluble or decomposable substances". Although spent foundry sand is certainly waste of a similar nature to earth or rock fill, the presence of leachable contaminants picked up during the moulding and casting process excludes this material from classification as inert fill. Waste concrete and asphalt from road construction projects are currently considered to be inert fill, but have some restrictions on their use.

'Recyclable material' refers to "a waste transferred by a generator and destined for a site,

i. where it will be wholly utilized, in an ongoing agricultural, commercial, manufacturing or industrial process or operation used principally for functions other than waste management and that does not involve combustion or land application of the waste,

ii. where it will be promptly packaged for retail sale, or

iii. where it will be offered for retail sale to meet a realistic market demand,

but does not include hazardous waste or liquid industrial waste unless the transportation from generator to site is direct". Recyclable materials are considered to be raw materials, and are therefore exempt from registration and all other provisions of Ontario Regulation 347. The issue of whether or not the operation constitutes waste management or

recycling is decided by determining if the ongoing operation would be viable if the waste material was not available. If the operation requires the waste to be viable, then it is considered to be waste management. In addition, the operation must wholly utilize the material, and contaminant levels must be similar to raw materials.

It is this classification that is of greatest potential interest to the spent foundry sand generators. Given that spent foundry sand from most generators can be classified as non-registrable, non-hazardous waste, and there are a number of alternative uses where spent sand can be utilized as a partial replacement for other materials in an existing commercial or industrial operation, this byproduct can largely be considered to be recyclable material on a case-by-case basis. As such, it is exempt from the requirements of Ontario Regulation 347 and Part V of the EPA, and can be wholly used in an ongoing operation.

The appropriateness of this classification to spent foundry sand was discussed with representatives of MOEE as part of this Study (D. Tolson, Industrial Waste Specialist and G.P. Venkateswaran, Industrial Waste Policy Officer, both of MOEE Industrial Waste Policy Unit, Waste Management Branch). Although waste concrete and asphalt can be managed as inert fill, asphalt is restricted to applications where there is minimal potential impact on ground or surface water. Asphalt and concrete are preferred for parking lot and road construction where the use will not impact on future construction, and consideration is recommended to ensure that water supplies are protected. As the presence of phenols in spent foundry sand can impart a foul taste to water (particularly if chlorinated), it would be advisable to apply the same consideration.

What is the direct impact of this classification? In essence, it means that most spent foundry sands are exempt from Ontario Regulation 347 and Part V of the Environmental Protection Act, and could be recycled in many of the alternative uses previously discussed. Neither the generator nor the spent sand recycler needs a Certificate of Approval as is required under Part V of the Environmental Protection Act for such operations. Therefore, much of the Ontario spent foundry sand could be recycled in granular base and subbase, as fine aggregate in asphalt or concrete products, or as cement kiln feed. However, it should be recognized that other Parts of the Act still apply - for instance, if spent foundry sand is to be used in asphalt concrete or as cement kiln feed, the Certificate of Approval (Air) requirements of Section 9 of the EPA must still be considered.

Spent foundry sand often contains oversized materials, cores, core butts and tramp metals which would have to be screened out, crushed or separated for some recycling applications (any use where gradation is a requirement for instance). Similarly, in order to develop stockpiles of sufficient size that consistency can be achieved (i.e. day-to-day variations in the material characteristics can be homogenized by proper blending in a comparatively large stockpile), it might be necessary to accumulate a significant quantity of spent sand in a central area at a specific plant or group of plants before transferring it to the recycling site. It is our understanding that both these operations would be interpreted as a processing stage, which is allowed under the recyclable materials designation.

The presence of phenols in spent foundry sands is not specifically addressed by the Ontario Regulation 347 requirements, or other MOEE guidelines (such as Site Decommissioning and Cleanup Guidelines [7]). Phenols are essentially considered to be an aesthetic parameter owing to the foul taste that chlorophenolic compounds impart to drinking water -

leachable phenols combine with chlorinated drinking water to form chlorophenols. Ontario Provincial Water Quality Objectives (PWQO) have been developed to maintain the quality of surface (ambient) waters for the protection of aquatic life and recreation. The PWQO criteria quoted for phenols is 1 μg/L [9]. In addition to the PWQO guidelines, Ontario has also established Drinking Water Objectives to maintain the quality of drinking water. The term 'Maximum Desirable Concentration' (MDC) is used to define the limits on substances that are either aesthetically objectionable or conflict with good water control practices. The MDC recommended for phenols in drinking water is 2 μg/L [10], which is double the PWQO guideline. Chlorophenols are listed in the Ontario Drinking Water Quality Objectives as a substance having an 'undefined tolerance limit', a designation that is assigned to substances that may pose an adverse effect to health or the environment but for which there is insufficient scientific data to establish water quality objectives.

Storage of spent foundry sand, even if only temporary as a processing stage prior to transferring the material to a recycler, must consider the PWQO guidelines. Precipitation percolating through stockpiles will mobilize leachable phenols which must be removed from the runoff before it discharges into surface or ground water supplies. Fortunately, this can be accomplished with relative ease and at comparatively low cost through proper site design. This requires the design and construction of a temporary storage pad (impermeable base and sides to prevent leakage of any leachate) having suitable crossfall and capacity to collect any surface moisture or precipitation that has passed through the stockpiled spent foundry sand. The collected leachate is then discharged through an activated carbon filter. As phenols are highly mobile and dissipate rapidly, the phenols concentration of the stored spent foundry sand generally reaches acceptable levels within a relatively short period of time (one week to month, depending on the ambient weather (moisture) and seasonal conditions). Three such storage

pads were designed by JEGEL key staff and constructed in the late 1970s and early 1980s at sites in St. Catharines, Niagara Falls and Port Colborne in the Niagara Region for temporary storage of spent foundry sand from General Motors St. Catharines Foundry. Monitoring of the effluent from the activated carbon filtration unit was confirmed to satisfy PWQO guidelines. The only significant operating cost associated with this system is periodic replacement of the activated carbon, which can be completed on a turnkey basis by companies such as Calgon Carbon Canada Inc. The spent foundry sand from at least two of these locations was subsequently used as hot-mix asphalt fine aggregate.

The inert fill and recyclable materials definitions are currently under review by the MOEE. A proposed new definition of inert fill is included in the MOEE's Materials Management Policy proposal which is now out for public consultation. The proposed new definition is much more specific than the present one and does deal with phenolic compounds. Proposed 3Rs amendments focusing on certain waste streams such as paper, glass and plastic are being developed by the MOEE Waste Reduction Office (WRO). The review of the land application aspect of the recyclable material definition has been more recently commenced by the WRO in consultation with other Ministry offices. The directions of these regulatory initiatives will be to better facilitate legitimate 3Rs activities.

7.0 CONCLUSIONS

The survey of Ontario foundries confirms that the largest concentration of spent foundry sand is generated in south central Ontario, and coincides with the major market for aggregates as construction materials. A total of about 383,615 tonnes of spent foundry sand was generated by Ontario iron and steel foundries in 1991, with less than 10,000 tonnes by nonferrous foundries. About 95 percent of the sand generated is in the MOEE Southwestern, West Central and Central Districts.

It appears from the technical literature and review of current industry practices that the Ontario foundries and construction materials sectors have an established record of experience in the reuse and recycling of spent foundry sand that rivals or leads the North American and International communities. Use of spent foundry sand as hot mix fine aggregate and cement kiln feed has been ongoing since the early 1980s. Although these are clearly areas where the use of spent foundry sand could be expanded, these will undoubtedly continue to be significant areas for reuse and recycling, particularly if the foundry industry recognizes that spent foundry sand can be viewed as a useful value-added byproduct, not just a disposal problem.

Of potentially greater significance is the classification of spent foundry sand as a 'recyclable material', which would allow the waste to be recycled for certain purposes excluding land application (fill). This would allow spent foundry sand, after suitable processing to crush and/or screen out oversized material and produce a consistent gradation, to be recycled as granular base and subbase in road construction projects provided that the physical and chemical composition is compatible to the virgin material. Given that 82 million tonnes of granular materials are produced in Ontario each year for road construction purposes, this area

clearly has the greatest potential for recycling of spent foundry sand. Classification of spent foundry sand as a recyclable material exempts it from the requirements of Ontario Regulation 347 and Part V of the EPA. However, given the known presence of generally low levels of phenols in the spent foundry sand, it is recommended that spent foundry sand be handled in a similar fashion to waste asphalt and waste concrete from road construction projects (consideration must be given to ensure that water supplies are protected, as some spent foundry sands could impart taste and odour to water supplies).

A number of other potential uses of spent foundry sand were identified, including use as a supplementary concrete aggregate in products such as interlocking concrete pavers, calcium silicate bricks and mortars, unshrinkable fill, a fluxing agent in precious metals extraction, and hazardous waste vitrification. Extensive additional work would need to be completed to confirm the properties of individual spent foundry sands in concrete, while use as fluxing agent or hazardous waste vitrification are considered to be uses that are presently only technically and financially viable for the relatively small quantity of spent sand that is classified as hazardous. Use of spent foundry sand in hazardous waste vitrification technology is not considered to be recycling and is contingent upon this process being accepted in Ontario as a waste treatment option.

There are no significant technical or environmental approval impediments to recycling of spent foundry sand and the recyclable material designation requirements can be readily satisfied for most Ontario spent foundry sands and alternative uses. Care must be taken during any stockpiling/processing stage to ensure that any runoff from stockpiles meets Provincial Water Quality Guidelines (particularly for phenols), and this may necessitate construction of proper temporary storage pads and collection and filtration of any runoff before it leaves

the site. As this can be readily accomplished without significant technical, operational or economic impacts, the recycling of spent foundry sands can be greatly expanded, resulting in the more economic production of value-added products, the preservation of Ontario natural aggregate resources, and greatly reduced landfill disposal.

8.0 REFERENCES

1. Environment Ontario, Regulatory Measures To Achieve Ontario's Waste Reduction Targets, Waste Reduction Office Initiatives Paper No. 1, Ontario Ministry of the Environment, Toronto, Ontario, October 1991.

2. Emery, J.J., Mineral Aggregate Conservation - Reuse and Recycling Study, Prepared for Aggregate Resources Section, Ontario Ministry of Natural Resources, by John Emery Geotechnical Engineering Limited, Toronto, Ontario, February 1992.

3. American Foundrymen's Society, Inc., Final (Phase I) Report on Alternate Utilization of Foundry Waste Sand, Report prepared for the Illinois Department of Commerce and Community Affairs, Des Plaines, Illinois, July 1991.

4. Naik, Tarun R., Foundry Industry By-Products Utilization, Report No. CBU-1989-01, Center For By-Products Utilization, University of Wisconsin - Milwaukee, February 1989.

5. Gallagher + Associates in association with Robert Shnay Associates and Stevenson Kellogg Ernst & Whinney, The Foundry Industry In Ontario and Outlook For Industrial Minerals, Industrial Mineral Background Paper 7, Ministry of Northern Development and Mines, Toronto, Ontario, 1988.

6. D'Alessandro, L., Haas, R. and Cockfield, R.W., Feasibility Study on the Environmentally and Economically Beneficial Use of Waste Foundry Sand in the Paving Industry, Report prepared for Manufacturing Research Corporation of Ontario and Canadian Foundry Group, University of Waterloo, Waterloo, Ontario, November 1990.

7. Environment Ontario, Guidelines For The Decommissioning and Cleanup of Sites In Ontario, Ontario Ministry of the Environment, Waste Management Branch, May 1990.

8. Government of Ontario, Regulation 347, Revised Regulations of Ontario, 1990, as amended to O.Reg 555/92 under Environmental Protection Act (General - Waste Management), Queen's Printer for Ontario, 1992.

9. Ontario Ministry of the Environment, Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, Ontario Ministry of the Environment, May 1984.

10. Ontario Ministry of the Environment, Ontario Drinking Water Quality Objectives, Ontario Ministry of the Environment, 1984.

11. Johnson, Calvin K., Phenols In Foundry Waste Sand, Modern Casting, January 1981.

12. IRC and Malex Consultants Inc., Developments in Building Products: Opportunities for Industrial Minerals, Industrial Mineral Background Paper 13, Ontario Ministry of Northern Development and Mines, 1990.

13. Energy, Mines and Resources, 1989 Canadian Minerals Yearbook - Review and Outlook, Mineral Report No. 38, Energy, Mines and Resources Canada, 1990.

14. Canadian Portland Cement Association, Design and Control of Concrete Mixtures, Engineering Bulletin, Canadian Portland Cement Association, Fifth Edition, Ottawa, 1991.

15. Canadian Standards Association, Precast Concrete Pavers, CAN3-A231.2-M85, Canadian Standards Association, Rexdale (Toronto), Ontario, April 1985.

16. Anon., Building bricks from the waste pile, Environmental Science & Technology, Vol. 6, No. 6, June 1972.

17. Queensborough Glassworks, Recycling Waste Streams Using Glass Making Activities, Vitrification and Environmental Recycling Technology (VERT), Isle of Sheppey, U.K., October 1990.

18. Government of Ontario, Environmental Protection Act, Revised Statutes of Ontario, 1990, Chapter E.19, as amended by 1992 Chapter 1, SS-22-35, Ministry of the Attorney General, Queen's Printer for Ontario, June 1992.

APPENDIX A

DEFINITIONS

APPENDIX A
DEFINITIONS

These definitions are for the non-specialist and should not be considered technically complete. An extensive compilation of standard technical definitions is available from ASTM (ASTM, Compilation of ASTM Standard Definitions, 7th Edition, American Society for Testing and Materials, Philadelphia, 1990).

OPSS - Ontario Provincial Standard Specification
CSA - Canadian Standards Association

absorption: fluid entering permeable pores of a solid material, given as percent increase in mass.

aggregate: granular material of mineral composition, such as sand, gravel, crushed stone or processed blast furnace slag used in building and road construction (OPSS 1001, 1002, 1003, 1010 and CSA Standard A23.1).

antistripping additive: additive incorporated in an asphalt concrete to alleviate its stripping potential (physical separation of asphalt cement from aggregate, primarily due to moisture action).

asphalt: dark brown to black cementitious material in which the predominating constituents are bitumens that occur in nature or are obtained during crude petroleum refining.

asphalt cement (AC): asphalt that is refined to meet specifications for paving, industrial and special purposes (OPSS 1101).

asphalt concrete: plant hot mixture of asphalt cement and well-graded aggregate (HMA), placed and compacted into a dense mat in construction of asphalt pavement (OPSS 1150).

asphalt pavement: pavement consisting of surface and binder course asphalt concrete on supporting courses such as concrete base (composite pavement), asphalt treated base, cement treated base, granular base and/or granular subbase placed over the subgrade.

asphalt pavement surface recycling: see hot in-place recycling.

basecourse: layer of material immediately beneath the asphalt concrete or portland cement concrete surface of a pavement. (See asphalt pavement for instance.)

binder course: the lower asphalt concrete course(s) of a pavement.

blast furnace slag: nonmetallic byproduct of iron production in blast furnaces, consisting essentially of silicates and alumina-silicates of lime and other bases. Depending on the method of cooling the liquid slag, four types of blast furnace slag are produced: (1) air-cooled (solidification under ambient conditions), which finds extensive use in conventional aggregate applications; (2) expanded or foamed (solidified with controlled quantities of water, sometimes with air or steam), which is mainly used as a lightweight aggregate; (3) granulated (solidified by quick water-quenching to a 'glassy' state), which is mainly used in slag cement manufacture; and (4) pelletized (solidified by water and air-quenching in conjunction with a spinning drum), which is used both as a lightweight aggregate and in slag cement manufacture.

blended cement (blended hydraulic cement): intimate blend (interground and/or uniform blending) of portland cement with ground granulated blast furnace slag, fly ash or silica fume, in accordance with CSA Standard A362: (1) Type 10S - Portland Blast Furnace Slag; (2) Type 10SM - Slag-Modified Portland; (3) Type 10F - Portland Fly Ash; (4) Type 10FM - Fly Ash-Modified Portland; and (5) Type 10SF - Portland Silica Fume. (See supplementary cementing materials also.)

byproduct: secondary or incidental product to primary production material.

cement: portland cement (PC, CSA Standard A5) or blended cement (blended hydraulic cement, CSA Standard A362).

cement kiln: a rotating oven, operating at a temperature of about 1400°C to 1650°C, where raw materials for the manufacture of portland cement are changed chemically into cement clinker.

coarse aggregate: aggregate that is predominantly retained on the 4.75 mm sieve size.

cold recycling (cold asphalt pavement recycling): full or partial depth reuse of old asphalt concrete pavement (can be used for surface treatment, and can include treated and untreated base) that is either processed in-place or at a central plant, typically with the addition of emulsified asphalt (or other additive such as cutback asphalt, lime or cement) to achieve desired cold mix quality, followed by placement and compaction.

concrete (portland cement concrete, PCC): composite material consisting essentially of a mixture of cement and water (binding paste) with which are mixed particles of fine and coarse aggregates (CSA A23.1).

crushed gravel: aggregate, from crushing of gravel, with substantially all particles having at least one fractured (crushed) face. (Various agency specifications will have specific crushed material definitions and requirements to meet for various aggregate applications, OPSS 1003 for instance.)

crushed stone: aggregate, from crushing of quarried rock, with all faces fractured (crushed).

crusher run: aggregate, from a crushing plant, that has not been screened into various sizes.

demolition waste (building rubble): material, resulting from the demolition of building elements such as walls, floors and foundations, generally in a rubble form consisting mainly of concrete, brick, plaster, wood, steel and piping.

DFC (Dense Friction Course): dense friction course hot-mix asphalt concrete surfacing as specified in OPSS Form 1149, for use primarily on high speed (> 80 kph), high traffic volume highway and freeway roads.

excess material: rock, earth, aggregate, old asphalt concrete, old concrete, wood, etc., resulting from construction, that cannot be used at the site.

fill: material placed to level or raise the height of a site.

fine aggregate: aggregate that predominantly passes the 4.75 mm sieve size and is retained on the 75 μm sieve size.

fly ash (pulverized fuel ash, PFA): siliceous, fine, solid particles, from pulverized coal burning power plants, carried upwards by the combustion gases and collected in air emission control equipment (electrostatic precipitators).

foundry sand (spent sand, waste sand): silica sand used in ferrous and nonferrous foundries in the moulds, that becomes 'contaminated' during the casting process, and is reused, regenerated (recycled) or wasted.

full depth recycling: full thickness of old asphalt concrete or concrete (PCC) processed and recycled.

glass: vitreous material from the fusion of silica sand and soda ash with additional ingredients such as cullet and colouring additives.

Glasphalt: hot mix asphalt concrete (HMA) in which processed waste glass (unrecyclable glass) replaces some of the aggregates (bonding/antistripping additive of about one percent hydrated lime typically required).

granular: aggregate used in granular base, granular subbase or select subgrade (OPSS 1010).

gravel: granular material consisting of rounded, water-worn rock fragments 2 mm to 75 mm in size usually intermixed with sand.

hot asphalt pavement recycling (hot mix recycling, recycled hot mix, RHM): removal (surface milling or full depth) of old asphalt concrete (reclaimed asphalt pavement, RAP), processing, heating and mixing in a hot mix plant (batch, drum or combined) with new aggregates and new asphalt cement (softer grade or with recycling agent), relaying and compacting to meet specifications for conventional hot mix asphalt concrete (HMA).

hot mix asphalt concrete (hot mix, hot mix asphalt, HMA): designed aggregate and asphalt cement mix produced in a hot mix plant (batch, drum or combination) where the aggregates are dried, heated and then mixed with heated (fluid) asphalt cement (hot mix), then transported, placed and compacted while still at an elevated temperature (about 125 to 135°C) to give a durable, deformation resistant, fatigue resistant pavement course.

hot in-place recycling (asphalt pavement surface recycling): hot reworking of the surface of an aged asphalt pavement (typically up to 50 mm) using preheaters and a heat reforming machine, typically with the addition of a rejuvenator, aggregate or new hot mix (HMA) to restore the condition of the scarified old asphalt pavement, and sometimes with an integral surface course overlay, all suitably placed and compacted in a single or multi-pass process.

kiln dust (cement and lime kiln dust): dust particles generated from the calcining of raw materials in kilns, during the manufacture of cement or lime, that are carried out by the exit gases and captured in dust collection systems.

kiln feed: materials added to a cement kiln to form portland cement. The raw materials (typically high quality limestone or dolomite and gypsum) must contain appropriate amounts of lime, iron, silica and alumina, with supplementary materials frequently added to make up any deficiency (for example, fly ash can be added as an additional source of silica and iron).

lime: all classes of calcitic (high calcium) and dolomitic quicklime and hydrated lime.

limestone: sedimentary rock composed principally of calcium carbonate (calcite) or the double carbonate of calcium and magnesium (dolomite).

manufactured sand: fine aggregate produced by the crushing and processing (does not include screenings) of quarried rock, boulders, cobbles or gravel from which the natural fine aggregate has been removed (OPSS 1001).

materials recovery: initial phase of waste processing in which recyclable materials are extracted.

milling (cold planing): removing surface of an asphalt concrete pavement, using a travelling machine equipped with a transverse rotating cutter drum (milling head with tips), typically 25 to 75 mm in depth. The resulting asphalt concrete millings (form of reclaimed asphalt pavement, RAP) are usually recycled.

mineral fibre rock, slag, or glass thermal insulation: insulation composed principally of fibres manufactured from mineral substances such as rock, slag, or glass with or without binders.

mineral filler: finely divided mineral product, at least 70 percent of which passes the 75 μm sieve size (hot mix asphalt use), such as pulverized limestone (most common manufactured filler). (The term 'filler' is often used with hot mix asphalt for all of the minus 75 μm sieve size material.)

nepheline syenite: a mineral aggregate consisting chiefly of albite, microcline, and nephelite each in a significant amount, used as a raw material in the manufacture of glass, rock wool insulation and ceramics.

OFC (Open Friction Course): open friction course hot-mix asphalt concrete surfacing as specified in OPSS Form 1149, primarily used on high speed (> 80 kph), high volume highway and freeway pavements in urbanized areas due to its superior drainage and noise reduction attributes.

pavement structure: all courses (components) of a pavement above the subgrade to the traffic surface such as granular subbase, granular base, treated (asphalt or cement) base, asphalt concrete (HMA) and concrete (PCC).

pozzolan: siliceous or alumino-siliceous material that, in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide to form compounds having cementitious properties.

portland cement concrete (PCC): see concrete.

portland cement concrete recycling: see concrete recycling.

reclaimed aggregate material (RAM): removed and/or processed pavement materials containing no reusable asphalt cement.

reclaimed asphalt pavement (RAP): removed and/or processed pavement materials containing asphalt cement and aggregates.

reclaimed concrete (reclaimed concrete material, RCM): removed and/or processed old portland cement concrete (PCC).

reclamation: restoration to usefulness or productivity of materials found in the waste stream, including reclaimed materials used for purposes different from their original usage.

recycling: when material is reclaimed from the waste stream and used as raw material in the manufacture of the same or a similar product, usually after varying degrees of processing. (For instance, reclaimed asphalt pavement (RAP) used in Recycled Hot Mix (RHM).)

recycled hot mix (RHM): hot mix asphalt concrete that contains processed reclaimed asphalt pavement (RAP). (See hot asphalt pavement recycling.)

residue: material remaining after completion of a chemical or physical process such as combustion, evaporation, distillation or filtration.

resource conservation: combination of waste reduction, reuse and recycling (sometimes termed the 3 Rs).

resource recovery: extraction and use of material(s) from a waste stream.
reuse: when material is used more than once by reclaiming from the waste stream, with little or no processing. (For instance, refillable containers are a reuse application.)
reworking: processing existing unbound pavement materials in place, such as granular base, mechanically and/or by stabilization to improve performance.
rock wool insulation: see mineral fibre rock, slag, or glass thermal insulation.
rubble: see demolition waste.
sand: fine aggregate resulting from natural disintegration and abrasion of rock or processing of completely friable sandstone. (See manufactured sand and screenings.)
screenings: fine aggregate including dust (minus 75 μm) produced by the crushing of quarried rock, boulders, cobbles or gravel from which the natural fine aggregate has been removed. (Typically a byproduct of crushing and processing quarried rock or gravel for asphalt and concrete coarse aggregates.)
secondary materials: materials handled by dealers and brokers that have fulfilled their useful function and usually cannot be used further in their present form or at their present location, and materials that occur as waste from the manufacturing or conversion of products.
silica fume: finely divided residue, resulting from the product of silicon or silicon-containing alloys, which is carried from the production furnace with the exhaust gases and collected in the air emission control equipment (electrostatic precipitators).
slag cement: see supplementary cementing materials.
slag: molten byproducts, from the smelting or sintering of metallic ores, that are cooled by various methods.
solid waste management: conduct and regulation of the entire process of generation, storage, collection, transportation, processing, reduction, reuse, recovery and disposal of solid waste.
steel slag: byproduct slag, that is developed simultaneously with steel in basic oxygen, electric, and open hearth (few in use) steelmaking furnaces, consisting essentially of calcium silicates and ferrites combined with fused oxides of iron, aluminum, manganese, calcium and magnesium, including 'foreign' materials such as unhydrated lime (free CaO) that require special treatment before use.
stone: any natural rock deposit or formation of igneous, sedimentary and/or metamorphic origin, usually used as dimension stone or crushed stone in building or road construction.
subbase course: layer of material in a pavement immediately above the subgrade. (see asphalt pavement for instance.)
subgrade: soil prepared through cut, fill and/or fine dressing to support a pavement. (See asphalt pavement for instance.)
supplementary cementing materials: material that, when used in conjunction with portland cement, contributes to the properties of the hardened concrete through hydraulic and/or pozzolanic activity, in accordance with CSA Standards A23.5 and A363: (1) Type N - Natural pozzolan; (2) Types F- Class F fly ash (normally from burning anthracite or bituminous coal); (3) Type C - Class C fly ash (normally from burning lignite or sub-bituminous coal); (4) Type G - Ground granulated blast

furnace slag; (5) Type H - Cementitious hydraulic slag (CSA Standard A363); and (6) Type U - Silica fume.

surface course: top hot mix asphalt course (HMA) of a pavement, sometimes called asphalt wearing course. (See asphalt pavement for instance.)

sustainable development: using natural resources in such a way as to meet current economic and social needs, but not depleting or degrading these resources to the point that they cannot meet these needs for future generations.

waste: wide variety of materials which are discarded or rejected as being spent, useless, worthless or in excess.

waste rock: coarse material which is broken and removed during quarrying or mining operations to expose the usable rock or ore, respectively.

APPENDIX B

APPENDIX B1 - PAVEMENT DESIGN AND CONSTRUCTION TERMINOLOGY

APPENDIX B2 - TYPICAL SPECIFICATION PROVISIONS FOR WASTES AND BYPRODUCTS USE

APPENDIX B1
PAVEMENT DESIGN AND CONSTRUCTION TERMINOLOGY

PAVEMENT STRUCTURES

Typical conventional pavement structures (Figure B1) are made up of layers of granular subbase, granular base and surfacing, designed to support the traffic loadings (magnitude and replications) for the site subgrade and environmental conditions. The pavement surface is normally hot-mix asphalt concrete (HMA), portland cement concrete (PCC), plant or road-mixed mulch, cold mix or surface treatment.

Depending on the specific technically-sound, cost-effective design adopted (influence of local soil conditions for instance), the granular subbase and/or base may be omitted or replaced with cement treated, asphalt treated or lean concrete base, or an open-graded drainage layer. In composite pavements, the PCC base forms part of the pavement. The subgrade may also be improved (stabilized) with materials such as lime and fly ash.

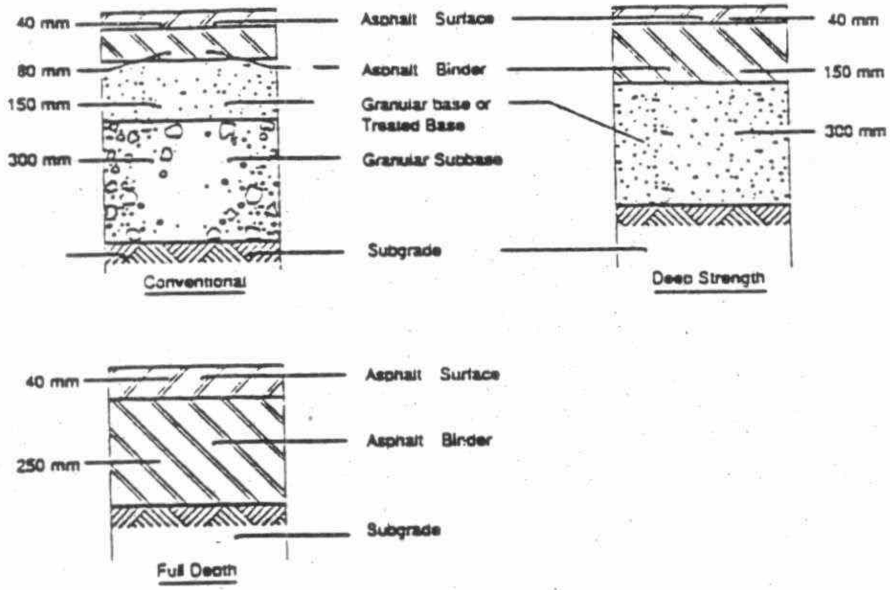
Functions and Characteristics of Flexible Pavement Structure Layers

Wearing Course - Generally a dense, highly stable, durable, good frictional properties surface course HMA which carries the traffic. It must resist the elements and keep water out of the underlying materials. The surface course HMA type is selected on the basis of its wearing, durability, friction and strength properties.

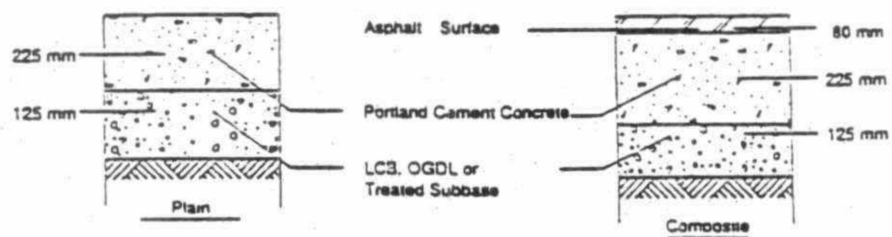
Binder Course - Lower layer(s) of HMA. It is normally distinguished from the surface course when there is a difference in the quality of the hot mixes used. It adds much to the overall strength of the pavement structure, supports the surface course and distributes load to the base.

The following mechanical properties are of importance to the performance of HMA:

1. elastic stiffness;
2. resistance to fatigue cracking; and
3. resistance to permanent deformation (rutting).



FLEXIBLE PAVEMENTS



RIGID PAVEMENTS

FIGURE B1
FLEXIBLE AND RIGID PAVEMENT STRUCTURES
(Adapted from MTO Pavement Design
and Rehabilitation Manual.)

Granular Base Course - Carries a large portion of the load, provides some drainage, minimizes frost action and allows fine grading for surfacing. It is generally specified as high stability, graded, crushed gravel or stone.

Granular Subbase Course - Normally a non-processed aggregate obtained from local gravel pits. Performs the same function as a granular base course except that it can be of lower quality.

Subgrade - This is the 'foundation' for both flexible and rigid pavement structures. It is the uppermost material placed in embankments or remaining in cuts. It carries the pavement structure and distributed wheel load stresses.

GENERAL REQUIREMENTS FOR AGGREGATES IN PAVEMENTS

Aggregates for use in granular subbase, granular base, treated base, HMA, PCC, etc. must be carefully specified/selected to perform satisfactorily in terms of function (vehicle load stresses for instance) and durability (frost resistance for instance). The Ontario grading and physical requirements for aggregates in pavements and transportation structures are typically based on MTO test procedures (LS), which simulate field conditions, and OPSS reflecting practical MTO usage experience: Los Angeles impact and abrasion test (MTO LS603, ASTM C131); magnesium sulphate soundness test (MTO LS606, ASTM C88); 24-hour water absorption test (MTO LS604, ASTM C127); and petrographic evaluation leading to a petrographic number (PN, MTO LS609). (See Appendix B, Senior and Rogers, 1990, for a comprehensive review of MTO methods for predicting aggregate performance.)

The petrographic evaluation (PN) of an aggregate, or waste/byproduct being considered for use, is considered to give a good general indication of potential suitability and performance. The petrographic evaluation (PN) is a routine, subjective quality test for coarse aggregate used to assess soundness, durability, hardness and strength. Simple index tests are used to classify the individual aggregate particles into quality types according to rock type, strength, hardness, and degree of weathering. Four quality categories are recognized: good aggregate (Factor 1); fair aggregate (Factor 3); poor aggregate (Factor 6); and deleterious aggregate

(Factor 10). A petrographic number (PN) is calculated by multiplying the percentages of each group by the appropriate factor and adding up to arrive at the total PN. The higher the PN, the lower the quality of the aggregate. The weighting factors for certain categories of aggregates are different, depending on whether the aggregate will be used for HMA, PCC or granular material.

While MTO experience indicates the PN to be an essential procedure in the evaluation of aggregate quality, there are problems with the Los Angeles abrasion test and magnesium soundness test in terms of precision and correlation with aggregate field performance. In summary, MTO experience indicates that:

1. the likely performance of aggregates in granular base is best measured by the micro-Deval test (a form of abrasion or attrition test in a ball mill) and water absorption;

2. the physical performance of concrete aggregates is best measured by the micro-Deval test, water absorption and unconfined freezing and thawing (other tests such as alkali reactivity are very important);

3. the performance of asphalt concrete aggregates is best measured by the micro-Deval test, polished stone value test and unconfined freezing and thawing; and

4. petrographic examination is also an essential tool in the evaluation of aggregate quality.

It appears that the MTO will be adopting the micro-Deval and unconfined freezing and thawing tests over the next few years.

Granular Materials

1. **Granular Base**

Each agency will have a range of specified granular materials, such as the MTO four granular materials (Granular A, B, M and SSM) in Table B1, where physical and gradation requirements are given.

TABLE B1
ONTARIO PROVINCIAL STANDARD
SPECIFICATION (OPSS 1010) REQUIREMENTS
FOR GRANULAR MATERIALS

PHYSICAL REQUIREMENTS

PHYSICAL TEST	GRANULAR A	GRANULAR B TYPE I	GRANULAR B TYPE II	GRANULAR M	SELECT SUBGRADE MATERIAL	MTO LABORATORY TEST NUMBER
Los Angeles Abrasion Loss, %, Maximum	60	N/A	N/A	60	N/A	LS 603
Petrographic Number Maximum	200	250*	250	200	250*	LS 609
Plasticity Index	0	0	0	0	0	LS 704
Percentage Crushed Minimum	50	N/A	100	50	N/A	LS 607

*The petrographic number (PN) requirement is waived if the material has more than 80 percent passing the 4.75 mm sieve size.

GRADATION REQUIREMENTS***

Percentage Passing by Mass

MTO SIEVE SIZE	GRANULAR A	GRANULAR B TYPE I	GRANULAR B TYPE II	GRANULAR M	SELECT SUBGRADE MATERIAL
150 mm	N/A	100	100	N/A	100
37.5 mm	N/A	N/A	N/A	N/A	N/A
26.5 mm	100	50-100	50-100	N/A	50-100
19 mm	85-100 (87-100)*	N/A	N/A	100	N/A
13.2 mm	65-90 (75-95)*	N/A	N/A	75-95	N/A
9.5 mm	50-73 (60-83)*	N/A	N/A	55-80	N/A
4.75 mm	35-55 (40-60)*	20-100	20-55	35-55	20-100
1.18 mm	15-40	10-100	10-40	15-40	10-100
300 μm	5-22	2-65	5-22	5-22	5-95
150 μm	N/A	N/A	N/A	N/A	2-65
75 μm	2-8 (2-10)**	0-8 (0-10)**	0-10 (2-10)**	2-8	0-25

*Where the aggregate is obtained from a blast furnace slag source.
**Where the aggregate is obtained from a quarry or suitable slag source.
***MTO Laboratory Test Number LS 602.

NOTE: When Granular B is used for granular backfill for pipe subdrains, 100 percent of the material must pass the 37.5 mm sieve size.

Granular A - relatively fine, well-graded, high-crushed fraction, that can be compacted to a dense stable material that can be fine graded. Specified as base course and shouldering material, as well as surface course for some rural roads. (Granular A is generally not free draining.)

Granular B, Type I - coarser and wider gradation than Granular A and not required to have crushed fraction. Thus, generally not as stable as Granular A and specified as subbase course.

Granular B, Type II - crushed material, with a tighter gradation, used where Type I is not available and/or use of a higher quality subbase course is required. (Granular B is generally not free draining.)

Granular M - same physical requirements as Granular A but finer gradation. Low susceptibility to segregation and can be fine graded for shoulder and granular road maintenance.

Select Subgrade Material (SSM) - sand, to sand and gravel sized material, that is non-plastic. Generally a good quality fill and backfill, although lower performance characteristics than Granular A, B and M. In some cases, local fine sand can be used to achieve uniform subgrade performance and eliminate/reduce the need for subbase.

In addition to the above, free draining, open-graded granular base (untreated, cement treated or typically asphalt treated, OGDL) is now being adopted by the MTO and other agencies in Ontario. The OGDL aggregate is essentially 100 percent crushed coarse aggregate with a low minus 75 μm content (less than about four percent).

2. **Treated Granular Bases**

Granular materials can be treated with a number of additives to enhance their engineering properties. The majority of such treatments are undertaken to improve granular strength and stability under loading. Granular materials are also treated with additives to control dust or to reduce settlement. The three major material groups of additives for granular treatment are: portland cement; asphalts; and others (flyash/lime, calcium chloride, lignosulphonate, etc.).

Cement treated base (CTB - about 5 percent portland cement), lean concrete base (LCB - about 7 percent portland cement) and roller compacted concrete (RCC - about 12 to 14 percent portland cement, zero slump) are terms used to describe three types of portland cement treatment which are used to improve the stability of granular materials. It is important that the durability of CTB be checked for salt and freeze-thaw resistance.

Asphalt treatment of granular base materials improves the stability of the granular materials as well as providing increased resistance to the penetration of water. Bituminous treated base (BTB), as used by the MTO, consists of Granular A mixed with 3 to 3.5 percent asphalt cement in a central plant and placed with an asphalt spreader. In the short term, BTB provides an adequate wearing surface, however, due to its low asphalt cement content, it should be overlaid with hot-mix asphalt concrete to prevent ravelling. Emulsion Stabilized Base (ESB) is also used.

3. **Unshrinkable Fill**

Unshrinkable fill (controlled density backfill) is a fluid mix of sand, aggregate and a low percentage of portland cement (about 25 kg/m^3). The design compressive strength of the mix is typically 0.4 MPa at 28 days. The mix is used as trench backfill where settlement cannot be tolerated and to restore utility cuts on existing roads. Although the material cost of unshrinkable fill is higher than that of granular backfill, the ease of placement and the reduced maintenance costs over the long term can provide a cost-effective alternative to properly placed and compacted granular backfill. The use of unshrinkable fill in trenches where frost-susceptible material is present is not recommended since non-uniform road performance may result.

Asphalt Materials

Asphalt materials include a wide range of plant and road mixed materials comprising asphalt binder (asphalt cement, cutback asphalt or emulsified asphalt) and aggregates, with the following general properties:

1. resistance to surface wear;
2. reduced surface water infiltration;
3. smooth and rideable finish; and
4. structural support of wheel loads.

The MTO defines two broad classes of asphalt pavement surfaces:

1. Mix Systems
   - hot and cold mixed asphalt concrete
   - hot and cold mixed stabilized base
   - recycled hot and cold mixed asphalt concrete
   - travel plant cold mix
   - slurry seal

2. Layered Systems
   - penetration primer
   - surface treatment
   - macadam

Specific road/highway use, economic considerations and the functional requirements of the pavement type determine which asphalt material should be used to surface a road. The material and construction requirements for asphalt materials are typically covered by agency specifications (OPSS for instance).

1. **Hot-Mix Asphalt Concrete**

Hot-mix asphalt concrete (HMA) is a designed (typically Marshall method) mix of coarse and fine aggregates with asphalt cement binder which is mixed, placed and compacted in a heated condition. The MTO specifies (OPSS) a number of hot mix types:

HL 1 - dense-graded surface course mix, with a premium quality coarse aggregate (excellent frictional and wear properties, maximum 16 mm size), used on high-traffic volume highways.

HL 2 - sand mix (minus 9.5 mm) used as a levelling course, thin overlay on low speed areas and to fill wide cracks.

HL 3 - dense-graded surface course mix with aggregate gradation the same as HL 1 and lower physical properties requirements.

HL 3 Fine - fine, dense-graded surface course mix (minus 16 mm) used for hand work areas, minor municipal roads, driveways, boulevards, parking areas, etc.

HL 4 - dense-graded surface or binder course mix (minus 19 mm).

HL 8 - dense-graded binder course mix (minus 26.5 mm).

Heavy Duty Binder - dense-graded, high-stability binder course mix designed to resist rutting (100 percent crushed coarse and fine aggregates, HL 4 or HL 8 gradation).

Dense Friction Course (DFC) - dense-graded, premium surface course mix, with high frictional resistance (HL 1 gradation, physical properties of coarse and fine aggregates superior, trap rock for instance), used for high-speed, high-traffic volume highways.

Open Friction Course - open-graded, premium surface course mix, with superior quality aggregates, used in place of DFC where low tire noise desired (free draining with good frictional resistance).

Modified Mixes - hot mixes modified to suit required performance or the availability of materials (HL 4 Mod and HL 8 Mod are open-graded, well-draining binder course mixes for instance).

The types of coarse and fine aggregates used in HMA surface course mixes are summarized in Table B2.

TABLE B2
COARSE AND FINE AGGREGATE SOURCES FOR SURFACE COURSE HMA
(Must be on Designated Source List and/or Aggregate Source List.)

TYPE	TRAP ROCK	STEEL SLAG	BLAST FURNACE SLAG	GRAVEL	DOLOMITIC SANDSTONE
HL 1 Coarse	X	X	X	X	
HL 1 Fine			LOCAL	AGGREGATE	
DFC Coarse	X	X	X		
DFC Fine	X	X			
OFC Coarse	X	X			
OFC Fine	X	X			
HL 3 Coarse	X	X	X	X	X
HL 3 Fine	X	X	X	X	X

Note: It is very important that specific contract requirements, current specifications, and current source lists be checked for each project.

2. Cold-Mix Asphalt Concrete

Cold mix is a mixture of emulsified asphalt and aggregates produced, placed and compacted at ambient temperature. Liquid asphalt (cutback) is also used, however emulsified asphalt is normally specified due to its lower cost. The use of cold mix is generally restricted to low-volume roads, where hot-mix asphalt concrete surfaced pavements are not required. Cold mix asphalt concrete (dense or open-graded) can be mixed in a central plant or in-place on the road surface with a travelling mixer (Midland Mix Paver and road mix mulch pavements). Once the emulsified asphalt in the mixture surface starts to break, or set, the mixture is compacted. Open-graded mixes are relatively stony mixes containing less than 10 percent fine aggregate. Open-graded mixes are more commonly used than dense-graded mixes due to some difficulty in attaining uniform coating of the coarse aggregates in dense-graded mixes. The open-graded mixes are surfaced with a light choke-sand coating to seal the surface and to minimize aggregate pick-out by traffic. The mix surface is normally covered within a year with a single surface treatment (SST).

3. Surface Treatments

Surface treatments consist of an application of emulsified or cutback asphalt and select aggregate over a prepared granular base or existing surface. Following placement of the aggregate, the mixture is rolled and compacted to provide a driveable and dust-free surface. Emulsified asphalt is more commonly used than cutback asphalt due to its lower cost. This type of pavement surface is frequently used on light to medium volume roads which may or may not have an existing asphalt concrete surface cover. Surface treatment of a granular road serves to control the infiltration of water, provide frictional resistance, improve ride quality, and control dust and stone pick-up. Surface treatments are also applied over existing surface treated or asphalt concrete pavements to restore frictional resistance and reduce the infiltration of water. Surface treatment type selection and application rate are based on the traffic volume and existing road surface characteristics.

4. Other Asphalt Surface Treatments

Other types of asphalt surface treatments include mulch pavement, slurry seal, fog seal, primer, tack coat and granular sealing.

Slurry seal is a mixture of emulsified asphalt, well graded fine aggregate and mineral filler (cement for instance) applied in 3 to 6 mm layers. Slurry seal is applied over existing asphalt concrete pavement and is used to seal the pavement and prevent ravelling. It provides no structural strength. Slurry seal is generally applied to the pavement surface from a travelling plant via a spreader box. This treatment is predominantly used by urban municipalities. As an extension to conventional slurry seals, micro-surfacing (crushed aggregate/polymer modified emulsion slurry seal) use is developing in Ontario.

Portland Cement Concrete

Portland cement concrete (PCC) is a mixture of sand and gravel or crushed stone bonded by a hardened paste of portland cement and water (additives for workability, air-entraining, etc. are typically used). Portland cement concrete mixes are normally designed by the ready mix supplier/contractor to OPSS requirements. The characteristics of PCC which influence its placement and performance are:

1. **workability** - must be workable so that it can be placed and consolidated without excessive segregation or bleeding;

2. **curing rate** - must harden at a sufficient rate to allow use at the earliest time (for new PCC pavement construction the curing rate is normally several days);

3. **strength** - must develop sufficient strength to support the design loads. PCC pavements normally are specified to have a nominal design compressive strength of 25 MPa. Traffic can be allowed on the road when the concrete has a strength of 15 MPa. Flexural or splitting tensile strength requirements are also normally given. A typical specified minimum splitting tensile strength is 2.8 MPa at 10 days.

4. **durability** - must be able to withstand freeze-thaw cycles and the service environment; and

5. **volume stability** - must not experience severe volume change during curing or service life in order to minimize the potential for cracking and deterioration.

Properties of PCC which are of particular importance to pavement performance are durability and flexural strength. PCC should be of sufficient durability to resist the effects of freeze-thaw, salt penetration, sulphate attack and traffic abrasion. Flexural strength refers to the bending strength of the concrete required to support both the magnitude of the wheel loads and the number of load applications. These aspects of concrete behaviour and design are critical to concrete pavement performance.

APPENDIX B2
TYPICAL SPECIFICATION PROVISIONS FOR WASTES AND BYPRODUCTS USE

B 2.1 Aggregate Uses

OPSS 1001[1] Aggregates - General
- spent foundry sand included in lists of fine and coarse aggregates
- MTO tests for aggregates listed

OPSS 1002 Aggregates - Concrete

OPSS 1003 Aggregates - Asphaltic Concrete, Hot Mixed and Hot Laid
- spent foundry sand included

OPSS 1010 Aggregates - Granular A, B, M and Select Subgrade Material

OPSS 1149 Asphaltic Concrete - Hot Mix and Hot Laid Including Recycled and Speciality Mixes
- spent foundry sand included as fine aggregate
- OPSS 1149 is intended mainly for MTO use as it incorporates specific MTO materials selections, design, testing and payment requirements

MT 701 Specification for Hot Mix, Hot Laid Asphaltic Concrete (Metro Toronto)

Special Provision No. 199F30 - Management of Excess Material
- requirements for management of excess rock, earth, swamp material, aggregate, asphalt concrete, concrete, natural wood and manufactured wood materials resulting from a contract.

B 2.2 Cementitious Uses

Portland cement must meet the requirements of CSA Standard A5.

Blended hydraulic cements must meet the requirements of CSA Standard A362 and are specified as:

Type	Name
10S	Portland Blast Furnace Slag
10SM	Slag-Modified Portland
10F	Portland Fly Ash
10FM	Fly Ash-Modified Portland
10SF	Portland Silica Fume

[1] See References in Section B 3. for full citations and sources. It is important that specific contract requirements and current specifications are checked for each project.

B 3. REFERENCES

B 3.1 Specifications and Uses

The current edition of these references should be consulted as specifications and manuals are always subject to revision.

APAO, Construction Aggregate Consumer's Guide, Aggregate Producers' Association of Ontario, Mississauga, 1991.

ASTM, Compilation of ASTM Standard Definitions, 7th Edition, American Society for Testing and Materials, Philadelphia, 1990.

ASTM, "Construction", 1991 Annual Book of ASTM Standards, 1991: (See 1990 Construction Volumes for those not available until later in 1991.)
Volume 04.02/Concrete and Aggregates (July 1991);
Volume 04.03/Road and Paving Materials; Pavement Management Technologies (May 1991);
Volume 04.05/Chemical-Resistant Materials; Vitrified Clay, Concrete, Fiber-Cement Products; Mortars; Masonry (April 1991);
Volume 04.06/Thermal Insulation; Environmental Acoustics (October 1991).

ASTM, "Water and Environmental Technology", 1991 Annual Book of ASTM Standards, 1991:
Volume 11.04/Pesticides; Resource Recovery; Hazardous Substances and Oil Spill Responses; Waste Disposal; Biological Effects (August 1991).

CSA, "Portland Cement/Masonry Cement/Blended Hydraulic Cement", CAN/CSA-A5/A8/A362-M89, Canadian Standards Association, Rexdale, 1989.

CSA, "Concrete Materials and Methods of Concrete Construction/Methods of Test for Concrete", CAN/CSA-A23.1/A23.2-M90, 1990.

Metro, "Specification for Hot Mix, Hot Laid Asphaltic Concrete", MT 701, Revision 1, Metric, Transportation Department, Municipality of Metropolitan Toronto Transportation Department, January 1991.

MNR, "Geology, Properties and Economics", Limestone Industries of Ontario, Volume 1, Ontario Ministry of Natural Resources, Toronto, 1989.

MTO, "Specifications and Special Provisions", Contract Design, Estimating and Documentation Manual, Volume 2, Chapter E, Ontario Ministry of Transportation, Downsview, current.

MTO, Special Provision No. 199, Management of Excess Material, November 1988;

MTO, "Coarse Aggregates for HL1 and DFC", Designated Sources for Materials, DSM Number 3.05.25, current.

MTO, Laboratory Testing Manual, current.

OPSS, Ontario Provincial Standards, Ministry of Transportation, Municipal Engineers Association and Ministry of Environment, Ontario Provincial Standards Section, Ontario Ministry of Transportation, Downsview, current:
OPSS 1001, Material Specification for Aggregates - General, May 1988;
OPSS 1002, Material Specification for Aggregates - Concrete, May 1988;
OPSS 1003, Material Specification for Aggregates - Asphaltic Concrete, Hot Mixed and Hot Laid, May 1988;
OPSS 1004, Material Specification for Aggregates - Miscellaneous, January 1990;
OPSS 1010, Material Specification for Aggregates - Granular A, B, M and Select Subgrade Material, May 1988;
OPSS 1350, Material Specification for Concrete (Materials and Production), December 1983;
OPSS 1149, Material Specification for Asphaltic Concrete, Hot Mix and Hot Laid Including Recycled and Speciality Mixes, June 1990 (intended only for MTO projects); and
OPSS 1150, Material Specification for Asphaltic Concrete, Hot Mixed and Hot Laid, October 1989.

Rogers, C.A., "Search for Skid Resistant Aggregates in Ontario", 19th Forum on the Geology of Industrial Minerals, Proceedings, Ontario Geological Survey Miscellaneous Paper 114, 1983.

Rogers, C.A., "MTO Aggregate Specifications for Road Building and Related Construction", Aggregate Producers Association of Ontario Specifications Seminar, Ontario Ministry of Transportation, Downsview, January 1991.

Senior, S.A. and Rogers, C.A., "New Test Methods for Predicting Coarse Aggregate Performance in Ontario", Transportation Association of Canada Annual Meeting, Ontario Ministry of Transportation, Downsview, September 1990.

B 3.2 General Design Manuals and Handbooks

AI, "The Asphalt Handbook", Manual Series No. 4, 1989 Edition, Asphalt Institute, Lexington, 1989.

CPCA, Design and Control of Concrete Mixtures, Canadian Metric Edition, Fourth Edition, Canadian Portland Cement Association, Ottawa, 1984.

MTO, Pavement Design and Rehabilitation Manual, Ontario Ministry of Transportation, Downsview, January 1990.

B 3.3 Obtaining Specifications, Design Manuals and Handbooks

Asphalt Institute (Extensive publications list on all aspects of asphalt technology)
Executive Offices and Research Center
Research Park Drive
P.O. Box 14052
Lexington, Kentucky 40512

Aggregate Producers' Association of Ontario (Publications on all aspects of Ontario aggregates industry)
365 Brunel Road, Unit 2
Mississauga, Ontario L4Z 1Z5

American Society for Testing and Materials (Extensive publications list on all aspects of construction materials)
1916 Race Street
Philadelphia, Pennsylvania 19103

Canadian Portland Cement Association (Extensive publications list on all aspects of concrete technology)
116 Albert Street
Ottawa, Ontario K1P 5G3

Canadian Standards Association (Extensive publications list on all aspects of construction materials)
178 Rexdale Boulevard
Rexdale, Ontario M9W 1R3

Federal Highway Administration (US Department of Transportation) (Extensive publications list on all aspects of transportation facilities materials and construction)
Demonstration Projects Division
400 7th Street SW
Washington, D.C. 20590

Municipality of Metropolitan Toronto Transportation Department
30th Floor, The Simpson Tower
401 Bay Street
Toronto, Ontario M5H 2Y4

Ministry of Natural Resources (Publications on all aspects of Ontario aggregates)
MGS Publications Services
5th Floor, 880 Bay Street
Toronto, Ontario M7A 1N8

Ministry of Transportation (Extensive publications list on all aspects of transportation facilities materials and construction)
Contract Design, Estimating and Documentation Manual
Laboratory Testing Manual
Ontario Provincial Standards (Complimentary copies are available to government, college, university and OPS Committee staff from Ontario Provincial Standards Section, 416-235-3530.)
Pavement Design and Rehabilitation Manual
Administration Services Office
Lower Level, East Building
1201 Wilson Avenue
Downsview, Ontario M3M 1J8

APPENDIX C

GENERAL DESCRIPTION OF THE STEPS INVOLVED IN THE MANUFACTURE OF PORTLAND CEMENT

APPENDIX C
GENERAL DESCRIPTION OF THE STEPS INVOLVED IN THE MANUFACTURE OF PORTLAND CEMENT

Portland cements are hydraulic, in that they set and harden by reacting with water. This reaction process is called hydration, and the cement and water combine to form a stone-like mass.

Selected raw materials (containing suitable proportions of lime, silica, iron and alumina) are crushed, milled and proportioned such that the desired chemical composition is obtained. These raw materials are derived primarily from local naturally occurring carbonate rock types such as limestone or dolomitic limestone (main source of lime), and shales (typical source of silica, iron and some alumina in southcentral Ontario), with any deficiencies in the overall chemical constituents supplemented by use of a range of natural or byproduct materials that are added either as feedstock or fuel (for example, fly ash addition as a supplementary source of silica and alumina, metal scrap as a source of iron, etc.). Gypsum is also added at a rate of 4 to 6 percent as a set-control additive.

After blending, the ground raw materials are fed into the upper end of a rotating oven (called a kiln) operating at a temperature of about 1650•C. The raw mix passes through the kiln at a rate controlled by the slope and rotating speed of the kiln. The raw material is changed chemically into 'clinker', which is then cooled and pulverized. At this stage, gypsum is interground with the pulverized clinker as a set-control additive. Figures C1 and C2 illustrate the steps involved in conventional and dry-process cement manufacture.

There are 5 basic types of portland cement:

Type 10: 'Normal', a general purpose cement suitable for all uses where special properties provided by the other Types are not required. It is used where the cement or concrete is not subjected to sulphate attack from soil or groundwater, and there is not a concern for objectionable temperatures developed during the hydration process.

Type 20: 'Moderate' in terms of its resistance to sulphate attack and the heat of hydration developed internally. Because the lower heat of hydration and slower rate, large mass concrete structures poured incorporating Type 20 cement are less likely to crack, even during relatively warm conditions.

Type 30: 'High Early Strength' provides relatively high strength development at an early period, typically less than a week or so. Used when the concrete structure or object is to be put into service relatively quickly.

Type 40: 'Low Heat of Hydration', intended for use in large dams or gravity retaining structures where the heat generated during cement hardening must be minimized to prevent cracking.

Type 50: 'Sulphate Resistant', used only when the concrete is in direct contact with soil or water containing high concentration of sulphates, which can attack normal concrete. It generally gains strength at a slightly slower rate than conventional concrete.

In addition to the above Types, there are also blended cements consisting of a mixture of portland cement and pozzolan (such as fly ash or silica fume) or granulated blast-furnace slag combined either during grinding at the mill or by blending after grinding. For example:

Type 10S - Portland blast-furnace slag cement
Type 10SM - Slag-modified portland cement
Type 10F - Portland fly ash cement
Type 10FM - Fly ash-modified portland cement
Type 10SF - Portland silica fume cement.

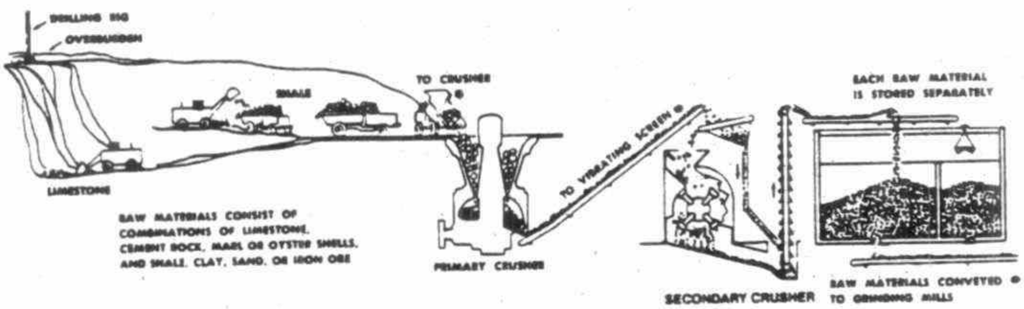
The requirements for the manufacture of portland cement, including the physical and chemical characteristics of the product, are detailed in CSA Standard A5, with the requirements for blended cements given in CSA Standard A362.

For practical purposes, portland cement consists of four principal compounds:

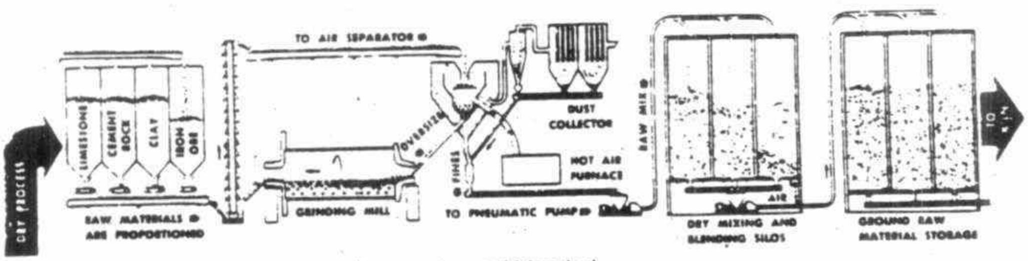
Tricalcium silicate	$3CaO \bullet SiO_2$
Dicalcium silicate	$2CaO \bullet SiO_2$
Tricalcium aluminate	$3CaO \bullet Al_2O_3$
Tetracalcium aluminoferrite	$4CaO \bullet Al_2O_3 \bullet Fe_2O_3$

The process involved is illustrated in the flow chart given in Figure C3.

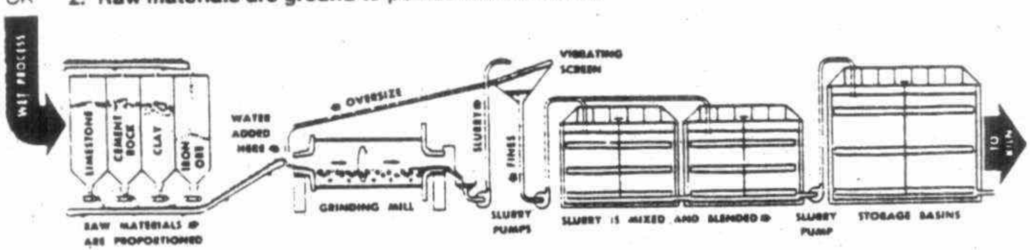
FIGURE C1
STEPS IN THE MANUFACTURE OF PORTLAND CEMENT



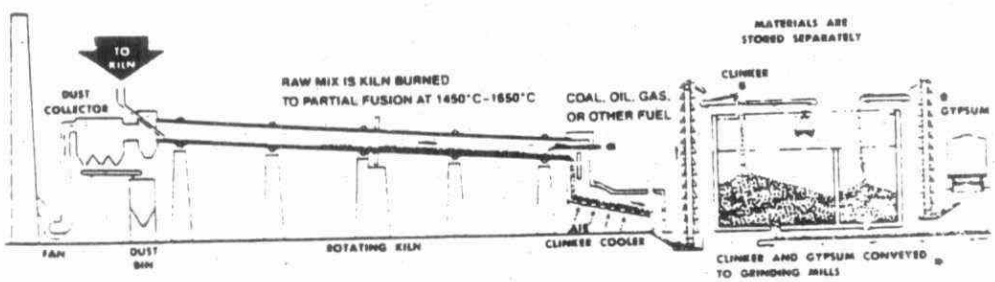
1. Stone is first reduced to 125 mm size, then to 20 mm, and stored.



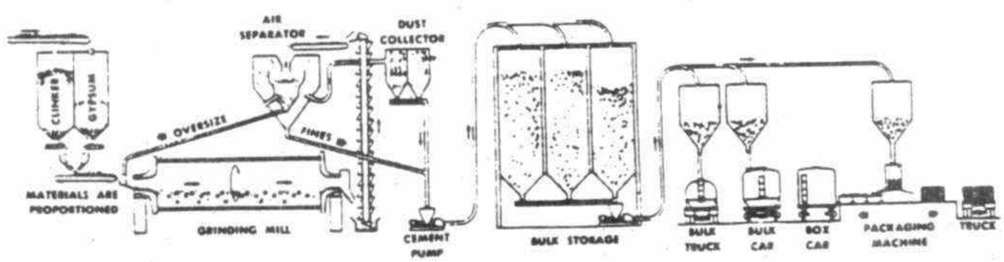
OR 2. Raw materials are ground to powder and blended.



2. Raw materials are ground, mixed with water to form slurry, and blended.

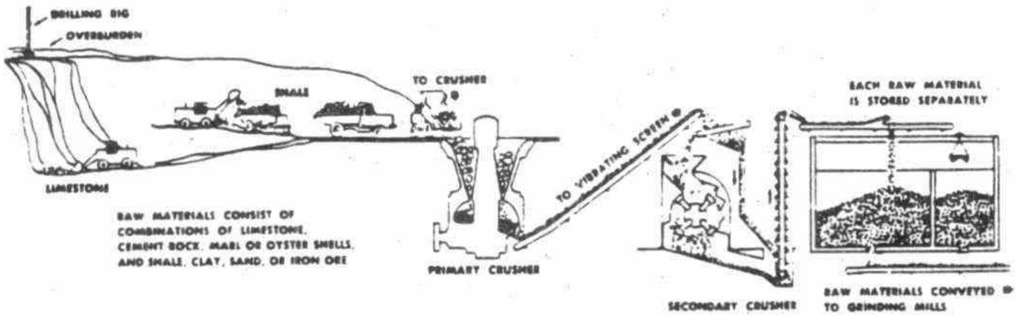


3. Burning changes raw mix chemically into cement clinker.

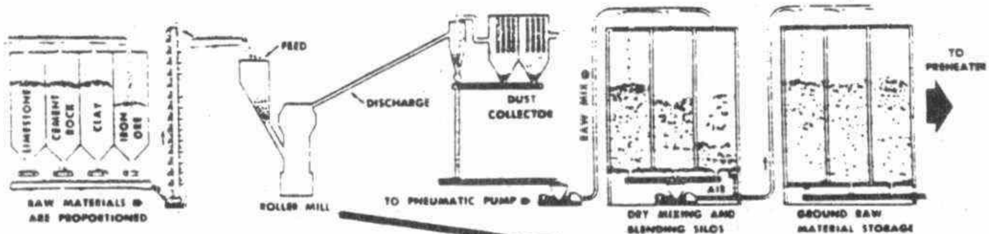


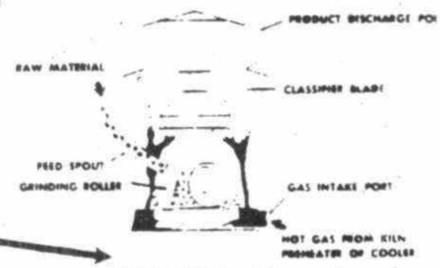
4. Clinker with gypsum is ground into Portland cement and shipped.

FIGURE C2
NEW TECHNOLOGY IN DRY-PROCESS CEMENT MANUFACTURE



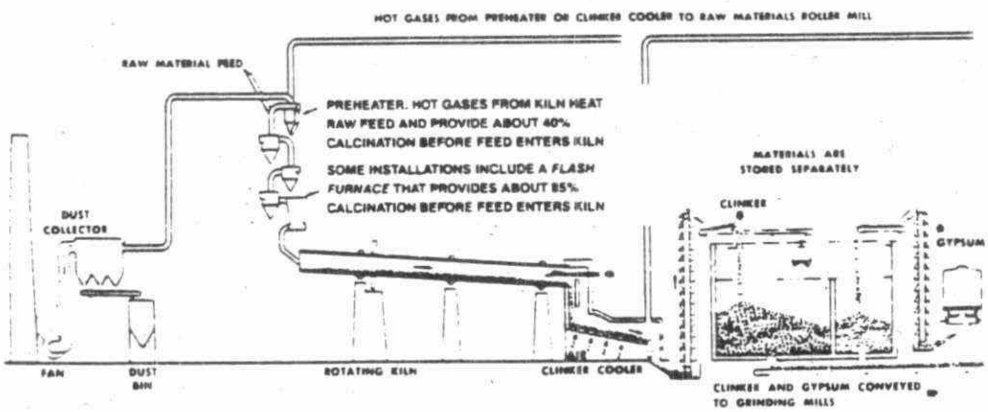
1. Stone is first reduced to 125 mm size, then to 20 mm, and stored.



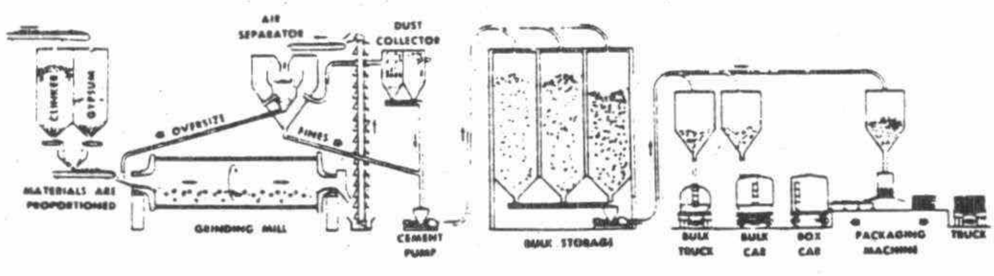


DETAIL OF ROLLER MILL, WHICH COMBINES CRUSHING, GRINDING, DRYING AND CLASSIFYING IN ONE VERTICAL UNIT

2. Raw materials are ground to powder and blended.

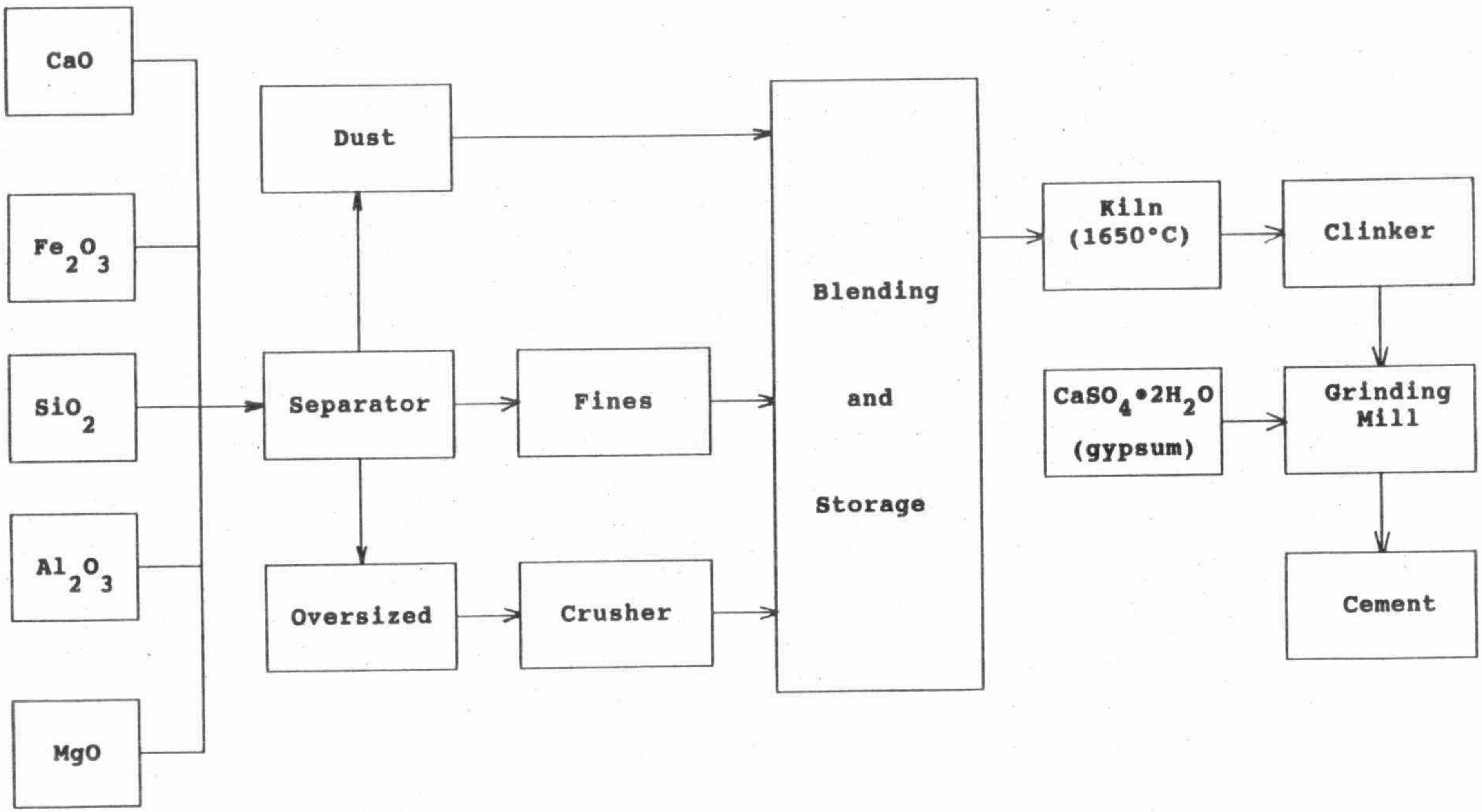


3. Burning changes raw mix chemically into cement clinker. Note four-stage preheater, flash furnaces, and shorter kiln.



4. Clinker with gypsum is ground into Portland cement and shipped.

FIGURE C3
PORTLAND CEMENT KILN
FLOW CHART



APPENDIX D

SELECTED ABSTRACTS ON SPENT FOUNDRY SAND CHARACTERISTICS AND UTILIZATION FROM DIALOG[R] SEARCH

5/7/2
1719917 MA Number: 91-511683
Metal Reclamation and Detoxification of Brass Foundry Waste Sand.
Tippin, R B
Author Affiliation: University of Alabama
Conference: Transactions of the American Foundrymen's Society. Vol. 97, San Antonio, Texas, USA, 7-11 May 1989
Publ: American Foundrymen's Society, Inc., Des Plaines, Illinois 60016-8399, USA, 1990
513-520
Journal Announcement: 9110
Document Type: BOOK
Language: ENGLISH
Abstract: For the past four years, University of Alabama Mineral Resources Institute has been involved in research directed toward the recovery of values from waste foundry material and the respective environmental problems. A major effort of this program has been the processing of waste molding sand from brass foundries for recovery of the contained metal and sand. In the past, most foundries have discarded this material, but recent regulations pertaining to Pb content have resulted in the waste sand being considered a hazardous waste. As a result of the research at the University of Alabama, a process has been developed using magnetic separation to recover approx 90% of the metal from the sand and subsequent sand calcining to meet EPA standards, thus permitting unregulated use. The brass metal concentrate is sold to a secondary refinery. The Fe concentrate, usually consisting of Fe shot and fine Fe dust from a shot blasting operation, can be returned back to the finishing operation, or disposed of in a sanitary landfill. The detoxified sand can either be reused within the foundry to make molds and cores, or sold as a by-product. A small fraction of the waste sand is rejected as "fines" which does not have economic value. Presently, two brass foundries have successfully adopted this process in their daily operation. One has been in operation since August 1987. Each system processes 100-150 tons/month of waste sand. Based on preliminary studies, several other foundries are considering installing similar systems. The recovery processes and resulting data from one of the plant operations are given. Graphs. 20 ref.--AA

5/7/4
1719890 MA Number: 91-511656
Plasma Processing: a Realistic Alternative in Thermal Sand Reclamation?
Leidel, D S ; Chu, F Y
Author Affiliation: Tanoak Enterprises, Ontario Hydro
Conference: Transactions of the American Foundrymen's Society. Vol. 97, San Antonio, Texas, USA, 7-11 May 1989
Publ: American Foundrymen's Society, Inc., Des Plaines, Illinois 60016-8399, USA, 1990
53-60
Journal Announcement: 9110
Document Type: BOOK
Language: ENGLISH

Abstract: Ever tighter environmental legislation and scarcer disposal sites have spawned great activity in sand reclamation research. Numerous publications in the past five years have reported about a wide range of research to process waste sand for reuse in the foundry. By definition, every reclamation activity itself generates a waste stream, i.e. the binder removed from the sand grains. However, there is a curious absence of information in practically all published reports with respect to this waste stream, which itself must meet environmental restrictions. Rather, the focus appears to be only on the aspect of reuse of the processed sand. It is concluded that plasma may well present an alternative to more effectively deal with the aspect of air pollution from the thermal processing of foundry sands than conventional thermal reclaimers. It must, however, also be recognized that there is no commercially proven equipment of this type available today. Design objectives are outlined which would have to be met to make this approach feasible. Also, a cursory cost analysis indicate that there may be a good possibility to indeed successfully employ plasma technology for the thermal processing of foundry sands. Photomicrographs, Graphs. 12 ref.--AA

5/7/8
1683934 MA Number: 90-511903
The Regeneration of Clay Bonded Molding Sands.
Roes, H L ; Wilhelm, L
Author Affiliation: G. Fischer
Giesserei 77, (13), 443-448 25 June 1990 ISSN: 0016-9765
Journal Announcement: 9012
Document Type: ARTICLE
Language: GERMAN

Abstract: The disposal of spent molding sands is increasingly more difficult and costly. The regeneration and separation of the molding sand ingredients has been accomplished by using a mechanical attrition method. The quartz particles, the bonding clay and the residual carbon material are separated and recycled to the molding shop. A pilot plant installed in a large steel casting operation has currently processed approx 100 tons of spent molding sands. The particle size distribution of the recycled quartz sand is very similar compared to virgin sand. A residual fraction of 12-15% of the spent sand must be disposed of and made up with virgin material. The goal of the experiments was the reduction of slag and molding sand inclusions in the steel. The molding sand preforms are suspended in the slag zone floating on the liquid steel bath. The highest reactivity was measured for quartz molding sand. Graphs. 2 ref.--F.J.B.

5/7/10
1662342 MA Number: 90-511011
Constructive Use of Foundry Process Solid Wastes for Landfill Construction: a Case Study. (Retroactive Coverage).
Martin, K E ; Stephens, W A ; Vondracek, J E
Author Affiliation: RMT, General Motors
Conference: Transactions of the American Foundrymen's Society. Vol. 95, St. Louis, Missouri, USA, 5-10 Apr. 1987

Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60016, USA, 1987
483-492
Journal Announcement: 9006
Document Type: BOOK
Language: ENGLISH

Abstract: A case study presented illustrates methods for using different foundry wastes in landfill construction projects. Using these materials in place of soils or other imported materials significantly reduced construction costs and met the necessary design specifications and state solid waste landfill standards for the facility. In addition to these benefits, the use of the wastes in construction saved valuable landfill space. A large gray and nodular iron foundry in the Midwest wanted to construct a 500 000-cubic yard disposal area for wet sludge generated by the foundry process. The design of the facility involved the construction of a 40 ft high berm of granular material on a 13-acre area. The interior of the disposal area would be lined with 2 ft of clay and a drainage collection system to facilitate dewatering. Constructive use of the general foundry process wastes instead of conventional construction materials (soils for the dike--sand/gravel for the drainage media) in the sludge disposal facility resulted in a direct cost savings of > $1 600 000 to the foundry, and an indirect savings due to the additional 260 000 cubic yards of disposal capacity that would have been occupied by soils. Graphs. 5 ref.--AA

5/7/11
1662331 MA Number: 90-511000

Effects of Process Parameters on Leachable Lead in Brass Foundry Sands. (Retroactive Coverage).

Mondloch, P A ; Becker, D W ; Euvrard, L
Author Affiliation: Kohler
Conference: Transactions of the American Foundrymen's Society. Vol. 95, St. Louis, Missouri, USA, 5-10 Apr. 1987
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60016, USA, 1987
385-392
Journal Announcement: 9006
Document Type: BOOK
Language: ENGLISH

Abstract: In December of 1978, the EPA published its proposed guidelines on identification of hazardous wastes. Since that time, foundries that cast leaded brass have had difficulty with their waste sands being classified as hazardous. The result of this has been escalating costs for disposal of the waste sand. The effects of several process variables on the leachable Pb content of the sand are studied. Pouring temperature was found to have a direct relationship to the leachable Pb content. Most of the Pb in the sand was found to be small elemental Pb nodules deposited on zinc oxide coated sand grains that are located within a few mm of the casting. It is concluded that treatment, reclamation, and permanent mold casting methods appear to be the most promising avenues around the sand Pb toxicity problem. Graphs, Photomicrographs. 2 ref.--AA

5/7/13
1651610 MA Number: 90-510396
The Leachability of Lead From Brass and Bronze Foundry Waste Sand Streams.
Ostrom, T R ; Trojan, P K
Author Affiliation: University of Michigan
Conference: Transactions of the American Foundrymen's Society. Vol. 96, Hartford, Connecticut, USA, 24-28 Apr. 1988
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60018, USA, 1989
435-442
Journal Announcement: 9003
Document Type: BOOK
Language: ENGLISH
Abstract: Research shows that a metallic Fe presence in the foundry sand waste inhibits Pb leaching in both the EPT and TCLP tests. The blocking mechanism may be due to the more anodic Fe displacing Pb from solution. Although ferrous or ferric sulfate in solution inhibits the Pb leachability, ferrous acetate does not prevent Pb from leaching. The presence of Fe ions in solution is no guarantee that Pb will not leach, since the anion (e.g. sulfate or acetate) plays an important role. A synthesized "acid rain" leaching solution reacts with Pb bearing waste sand to a much lesser extent than the acetic acid in the EPT and TCLP tests. There is then an advantage to a monofill disposal site where organic acid contents are negligible. When comparing 2 and 10 in. penetration test specimens, the ratio of Zn to Pb compounds is higher in the 2 in. samples. The shorter solidification time suggests that Pb compound formation is somewhat sluggish. A 1.5% seacoal addition to a southern bentonite bonded dry sand gave no detectable reaction product at the sand/metal interface of a 2 in. penetration sample. The metal penetration was also less than that found with an organic (cornflour plus dextrin) sand addition. , . 6 ref.--AA

5/7/17
1637127 MA Number: 89-512187
Process Parameters for Thermal Sand Reclamation.
Reier, G J ; Andrews, R S L
Author Affiliation: GMD Engineered Systems
Conference: 93rd AFS Casting Congress, San Antonio, Texas, USA, 7-11 May 1989
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60016-2277, USA, 1989
Pp 27
Report No.: Preprint No. 89-145
Journal Announcement: 8911
Document Type: REPORT
Language: ENGLISH
Abstract: Factors considered to be essential for a successful conversion from a conventional "open" sand system, uing new sand supplies and discarding the waste sand, to a "closed" sand system that uses a combination thermal/mechanical system for continually reclaiming a high percentage of the system sand and discarding a small percentage of waste sand are reviewed. Emphasis is placed on the absolute necessity for

consistency of sand properties in the reclaimed sand stream, particularly if it is planned to continuously return it for reuse in the core making operations. The operational economics are discussed in some detail in relationship to the residual binder fuels in waste streams of ferrous and non-ferrous foundry operations. Thermal efficiency is also discussed in terms of the oxygen content of the fluid-bed products of combustion for both clay and resin bonded mixtures going to the reclaimer, together with the special requirements for the reclamation of ester cured phenolics and styrene contaminated sand. The effect of current state and federal environmental regulations are also discussed. With the rapid closing of existing landfill sites and the prohibition of opening new ones, the necessity for limiting the generation of all types of industrial waste is becoming imperative. On the basis of economics alone, thermo-mechanical sand reclamation is the only technology available to the foundry industry to meet the requirements of the "Resource Conservation and Recovery Act" (RCRA). Graphs. 9 ref.--AA

5/7/18
1637072 MA Number: 89-512132
Plasma Processing--a Realistic Alternative in Thermal Sand Reclamation?
Leidel, D S ; Chu, F Y
Author Affiliation: Tanoak Enterprises, Ontario Hydro
Conference: 93rd AFS Casting Congress, San Antonio, Texas, USA, 7-11 May 1989
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60016-2277, USA, 1989
Pp 27
Report No.: Preprint No. 89-36
Journal Announcement: 8911
Document Type: REPORT
Language: ENGLISH
Abstract: Sand reclamation has become of great interest due to the necessity to reduce waste streams. It is often overlooked that this process itself generates waste that must be dealt with, the residual binder which is removed from the sand. While, specifically, thermal processing has gained in prominence, it must be stressed that here, too, one must comply with environmental restrictions. It is known that some reclaimers would not meet the existing environmental restrictions, specifically from overseas, where the legislative limits for emitted substances are often significantly wider than what is permissible in North America. Plasma processing promises to overcome some of these obstacles. Graphs, photomicrographs. 12 ref.--AA

5/7/19
1637056 MA Number: 89-512116
Metal Reclamation and Detoxification of Brass Foundry Waste Sand.
Tippin, R B ; Tate, R L
Author Affiliation: University of Alabama
Conference: 93rd AFS Casting Congress, San Antonio, Texas, USA, 7-11 May 1989

Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60016-2277, USA, 1989
Pp 33
Report No.: Preprint No. 89-83
Journal Announcement: 8911
Document Type: REPORT
Language: ENGLISH
Abstract: The recovery of values from waste foundry material and the respective environmental problems were studied. A major effort of this program has been the processing of waste molding sand from brass foundries for recovery of the contained metal and sand. In the past, most foundries have discarded this material, but recent regulations pertaining to Pb content have resulted in the waste sand being considered a hazardous waste. A process has been developed using magnetic separation to recover approx 90% of the metal from the sand and subsequent sand calcining to meet EPA standards, thus permitting unregulated use. The brass metal concentrate is sold to a secondary refinery. The Fe concentrate, usually consisting of Fe shot and fine Fe dust from a shot blasting operation, can be returned back to the finishing operation, or disposed of in a sanitary landfill. The detoxified sand can either be reused within the foundry to make molds and cores, or sold as a by-product. A small fraction of the waste sand is rejected as "fines" which does not have economic value. 20 ref.--AA

5/7/21
1618781 MA Number: 89-450826
Aims of Technical Progress in an Iron Foundry in Srem.
Bilewski, W
Przegl. Odlew. (5), 149-154 1988 ISSN: 0033-2275
Journal Announcement: 8906
Document Type: ARTICLE
Language: POLISH
Abstract: The iron foundry in Srem, Poland, was built between 1964-1973, and adopted the technology of those years which is can no longer acceptable. Among the problems tackled to rationalise technology is recycling of sand from molding and core mixes. Various methods of sand recovery are described in detail. Problems relating to technical waste management are discussed. Improvement in the output of fluidized sand driers, accomplished by a rise in the temperature of exhaust gases to 300-400 deg C, has reached approx 60%. 5 ref.--W.K.L.

5/7/22
1615194 MA Number: 89-510802
Disposal of Foundry Molding Sands in Accordance With Their Polycyclic Aromatic Hydrocarbon Contents.
Konig, J ; Balfanz, E ; Funcke, W ; Theisen, J
Author Affiliation: Gesellschaft fur Arbeitsplatz- und Umweltanalytik
Giesserei 75, (21), 627-630 10 Oct. 1988 ISSN: 0016-9765
Journal Announcement: 8905
Document Type: ARTICLE
Language: GERMAN
Abstract: Some polycyclic aromatic hydrocarbons (PAH) such as

benzopyrene, benzofluoroanthene and indenopyrene are carcinogens. They are formed in the workplace under various conditions. In the foundry, they are produced in the mold making department by reaction of certain organic substances added to the sands, e.g. glance carbon or pitch formers, polystyrene, starch, etc., which serve to produce smooth surfaces on the castings or to improve the rigidity of the mold, or both. In the wake of an increased awareness of the danger that carcinogenic PAH traces will find their way into the soil and drinking water near the foundry site or downstream, waste disposal questions have become of major importance. The present situation is appraised and suggestions are offered for a more judicious choice of the type of organic additives to be used in the sands, and of the foundry waste storage and disposal to be adopted. 9 ref.--C.G.G.

5/7/25
1585514 MA Number: 88-511504
Is the Profit Line the Bottom Line in Sand Reclamation?
Bralower, P M ; Burditt, M F
Mod. Cast. 78, (5), 27-34 May 1988 ISSN: 0026-7562
Journal Announcement: 8809
Document Type: ARTICLE
Language: ENGLISH
Abstract: With the prospect of fewer dumpsites and tighter restrictions, new technology and research promise greater rewards and fewer headaches using reclaimed sand. Reclamation systems in place of three foundries: Highland Foundry, Haley Industries, and Rockwell International, are studied. The different sand systems and the environmental and economic constraints that impacted these foundries' decisions were explored. Reclamation improves a foundry's economic wealth, sand systems, molding lines, waste disposal and, ultimately, casting quality. 5 ref.--A.R.

5/7/30
1555487 MA Number: 87-512104
Leaded Copper Alloy Reactions With Molding Sands and Sand Response to Acid Leaching. (Retroactive Coverage).
Trojan, P K ; Ostrom, T R ; Biel, J ; Flinn, R A
Conference: Transactions of the American Foundrymen's Society. Vol. 92, St. Louis, Missouri, USA, 30 Apr.-4 May 1984
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60016, USA, 1984
793-802
Journal Announcement: 8712
Document Type: BOOK
Language: ENGLISH
Abstract: Lead-reaction products, leach test results, and Pb removal techniques are considered. An interface test specimen and penetration experiments have been applied to a medium-Pb (CDA 83600) and high-Pb (CDA 94300) alloy. The higher Pb alloy gives higher metal penetration and more scale at the bentonite bonded sand/metal interface. Modest differences have been noted between olivine and silica sands. However, southern bentonite contributes more to Pb reaction products than western bentonite. The EP toxicity test for Pb does not correlate well with the total Pb content in

foundry sand waste. The test is more sensitive to metal particles and Pb oxides while less sensitive to Pb silicates. As a result, the Pb products identified in the interface and penetration studies gain greater significance. A low temperature thermal/mechanical sand reclamation system has been evaluated for its ability to modify foundry sand and the EP toxicity test Pb values. Longer treatment times and/or higher temperatures could reduce the Pb to < 5 ppm hazardous waste classification. 2 ref.--AA

5/7/31
1555473 MA Number: 87-512090
Planning for Thermal Sand Reclamation. (Retroactive Coverage).
Reier, G J ; Andrews, R S L
Conference: Transactions of the American Foundrymen's Society. Vol. 92, St. Louis, Missouri, USA, 30 Apr.-4 May 1984
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60016, USA, 1984
347-354
Journal Announcement: 8712
Document Type: BOOK
Language: ENGLISH
Abstract: The increasing costs of using new sand in both ferrous and nonferrous (Al, Cu, magnesium) foundries have resulted in the consideration of "universal sand reclamation". Results with mechanical methods of sand reclamation, to date, do not compare with the results possible with the hi-tech thermal--pneumatic method to be incorporated in computer-controlled closed sand systems in the immediate future. Such systems will reduce operating costs and improve product quality over a wide range of casting markets. To accomplish such a drastic improvement in foundry operations, this discussion highlights all plant engineering aspects that enter into planning: special material handling, determination of capacity, site selection, system operation, pollution control, and residual waste disposal. A fluid bed, thermal sand reclamation system can be installed with new sand systems or by retrofitting existing systems for both ferrous and nonferrous foundries. 8 ref.--AA

5/7/32
1552480 MA Number: 87-511931
Reclamation of a New Inorganic, Nobake Binder. (Retroactive Coverage).
Bolton, G J
Conference: Transactions of the American Foundrymen's Society. Vol. 91, Rosemont, Illinois, USA, 10-15 Apr. 1983
Publ: American Foundrymen's Society, Inc., Golf and Wolf Rds., Des Plaines, Illinois 60016, USA, 1983
95-100
Journal Announcement: 8711
Document Type: BOOK
Language: ENGLISH
Abstract: The reclamation and reuse characteristics of a new, inorganic, nobake binder have been tested in a multiple generation reclamation study. The generic classification of this binder is synthetic amorphous hydrogel (SAH). The purpose of this work is to determine if SAH-bonded silica sands,

reclaimed with equipment and procedures normally used for organically bonded sands, could produce several generations of good castings. A set of castings, selected to represent the ranges of alloys and casting types normally produced by the participating foundry, was made with SAH-bonded molds and cores. The lumps and loose sand were collected after shakeout. This spent sand was shipped to the laboratories of pneumatic reclaimer manufacturers for processing. The spent sands were granulated in vibratory attrition mills. The granulated sands were then pneumatically scrubbed and classified. Dust losses during reclamation ranged from 2-17%, with an overall average of 8.4%. The reclaimed sands were returned to the participating foundry for rebonding as molds and cores. This entire process was repeated for three cycles of castings. In all cases, the reclaimed sand was used without addition of new sand and at the same binder level used for new sand. In all cases, the castings were free of sand and/or binder related defects. 3 ref.--AA

5/7/33
1552389 MA Number: 87-511840
Lead Transfer From Copper-Base Alloys Into Molding Sand.
Ostrom, T R ; Winter, B P ; Trojan, P K
Conference: Transactions of the American Foundrymen's Society, Vol. 93, Pittsburgh, Pennsylvania, USA, 29 Apr.-3 May 1985
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60018, USA, 1985
757-762
Journal Announcement: 8711
Document Type: BOOK
Language: ENGLISH
Abstract: The initial phase of AFS-sponsored research has been directed toward the role of Fe in rendering leaded Cu alloy waste sand EP nonhazardous. Although 2 wt.% Fe powder gives 1 ppm Pb in a system sand initially containing 50 ppm Pb, larger Fe additions may be necessary when the Pb form changes. The Fe addition is less effective if Cu alloy is present, with increasing effectiveness when Pb is in the form of an oxide or silicate. The Fe must be pure or as cast iron rather than as an oxide or rust, to desensitize the sand. When active bentonite is present the leachable Pb decreases as long as Fe is not present. The precise role of Fe when added to active bentonite sands will require further experimentation; however, initial results suggest that larger Fe additions may be necessary to produce a nonhazardous waste when bentonite is present. 2 ref.--AA

5/7/34
1552387 MA Number: 87-511838
Methods to Treat EP Toxic Foundry Wastes and Wastewaters.
Turpin, P D ; Stolzenburg, T R ; Stephens, W A ; Kunes, T P
Conference: Transactions of the American Foundrymen's Society, Vol. 93, Pittsburgh, Pennsylvania, USA, 29 Apr.-3 May 1985
Publ: American Foundrymen's Society, Inc., Golf & Wolf Rds., Des Plaines, Illinois 60018, USA, 1985
737-740
Journal Announcement: 8711

Document Type: BOOK
Language: ENGLISH
Abstract: Foundries generate large quantities of solid waste, some of which may be classified as hazardous (EP toxic) due to the release of Pb and/or Cd in the USEPA extraction procedure test. One way to reduce disposal costs and regulatory requirements is to treat hazardous wastes so as to render them non-EP toxic. Wastes with a reasonable likelihood of being classified as EP toxic include melt emission control dusts or sludges from ferrous foundries, and a variety of dusts and waste sand from brass and bronze foundries. Chemicals such as ferric hydroxide, metallic Fe, phosphate, magnesium hydroxide, and lime have been used to treat EP toxic sludges, wastewater, and solid process wastes such as system sand and dusts. These chemicals either bind toxic metals by precipitation or adsorption, or change the solubility of the metals through pH control. Laboratory and field treatment studies have been successful in reducing Pb leaching from as high as 400 mg/l in the EP toxicity test, down to below the hazardous waste limit (5 mg/l). Cadmium leaching in the EP toxicity test is more difficult to control. Cadmium leaching was virtually unaffected by metallic Fe or iron hydroxide treatment at the pH values and dosages tested. Cadmium leaching can be reduced by controlling the final pH in the EP test. 2 ref.--AA

5/7/35
1552327 MA Number: 87-511778
New Knowledge in the Field of Reclamation and Optimal Reclamation Processes.
Polasek, B ; Sedlak, J ; Vesely, L
Slevarenstvi 35, (4-5), 160-167 1987 ISSN: 0037-6825
Journal Announcement: 8711
Document Type: ARTICLE
Language: CZECH
Abstract: For the selection of optimal reclamation processes, several important factors are considered: the composition of the sand, the binder used and its reclaimability and sensitivity to impurities, the purity of the reclaimed sand, maximum utilization of the reclaim in new mixtures, the cost of the reclaim equipment and process, and problems with air and water purification. New findings concerning the use of heat, effect of the alkalic wastewaters during chemical and chemico-thermal leaching will be instrumental in the use of optimal reclamation processes that will yield high quality reclaim. 7 ref.--V.T.B.

5/7/37
1545345 MA Number: 87-511524
Thermal and Mechanical Regeneration of Used Foundry Sand.
Bauer, H
Publ: VCH Verlagsgesellschaft, Postfach 1260/1280, D-6940 Weinheim, FRG, 1986
Waste Materials in Nonferrous Metallurgy--Further Utilization or Disposal 233-243
Journal Announcement: 8709
Document Type: ARTICLE
Language: GERMAN
Abstract: A dry process for regenerating used foundry sand, also called

foundry waste sand, is described. This process allows all types of quartz-sand bonding agents, such as clay, synthetic resins, water glass and cement to be handled. The essential processing stages include magnetic separation, fluidized bed treatment and counterflow impact. The regenerated sand may be reused. The possibility of reuse of the other byproducts leading to very little waste is discussed.--AA

5/7/42
996302 MA Number: 86-511823
Residual Materials in Foundries. Collection--Use--Removal of Waste.
Zindler, G
Giesserei 73, (3), 66-68 3 Feb. 1986 ISSN: 0016-9765
Journal Announcement: 8612
Document Type: ARTICLE
Language: GERMAN
Abstract: Laws and specifications for waste disposal are reviewed. The most important waste materials in foundries and their origin are discussed. Particularly critical is waste which may pollute water. The cost of waste disposal increases significantly if different solid pollutants are not kept separate. Careful planning and proper programming make effective waste disposal in foundries economically feasible. 4 ref.--F.V.

5/7/49
959041 MA Number: 86-510091
Research and Experimental Studies on the Harmfulness for the Natural Environment of the Wastes From Foundry Technologies.
Pr. Inst. Odlew. 34, (4), 201-219 1984 ISSN: 0449-959X
Journal Announcement: 8601
Document Type: ARTICLE
Language: POLISH
Abstract: Research and experimental works referring to the kinds and quantities of chemical substances in dumped sand mixes are presented and their influence on the natural environment is defined. The research included various types of dumped mixes originating from selected foundries. The type of the chemical substances and their concentration in the mixes was determined on a laboratory scale by the column method and on a semi-commercial scale under the conditions of atmospheric wastes on a test stand placed in the grounds of the Foundry Institute in Cracow, Poland. Definition of the charges of the chemical substances made it possible to evaluate the harmfulness of the mixes dumped and thus of their influence on the environment, mainly on the soils and waters during storage on the dumping ground. 6 ref.--AA

5/7/50
958989 MA Number: 86-510039
Reclaiming Foundry Sand--an Overview.
Miske, J C
Foundry Manage. Technol. 113, (8), 20-22, 24, 26-27 Aug. 1985 ISSN: 0360-8999
Journal Announcement: 8601

Document Type: ARTICLE
Language: ENGLISH
Abstract: Virtually every year, the cost of using new sand and disposing of old sand increases significantly. Environmental problems associated with waste disposal are particularly serious. One way to minimize the problem is to minimize waste material, which in foundries is mainly sand. Reclamation is increasingly attractive. The feasibility and specific requirements of reclamation are outlined. The flow diagram of a typical chemically bonded mold/core sand reclamation system is presented. The operation of the first commercial reclamation center operated in Birmingham is described. Currently, the principal methods of sand recovery are wet washing, dry scrubbing (pneumatic, mechanical or shot blast), and calcination (thermal).

5/7/57
902725 MA Number: 84-511282
Trends in Introduction of Low Waste and Waste-less Casting Processes.
Dafinov, I ; Velev, L ; Bankov, I ; Berov, V
Mashinostroene 32, (10), 447-449 Oct. 1983 ISSN: 0025-455X
Journal Announcement: 8409
Document Type: ARTICLE
Language: BULGARIAN
Abstract: The present state of the industry in Bulgaria and the possibilities of introducing further low waste processes for the production of cast iron and steel castings so as to reduce the contamination of the environment, are discussed. The main developments are expected to be the introduction of centrifugal casting for the production of tubes, the introduction of induction furnaces to provide metal of controlled chemical composition and physical-mechanical properties with the minimum consumption of raw materials and the introduction of mechanized casting lines with the dry regeneration of the molding sand and the consequential reduction in the consumption of binders. Further extension of rpocess optimization is expected to lead to increased output.--A.S.W.

5/7/59
899052 MA Number: 84-510990
Reclaiming Cold Setting Mold Sands in Nonferrous Casting Production.
Musiyachenko, A S ; Shantarina, V I
Liteinoe Proizvod. (12), 14 Dec. 1983 ISSN: 0024-449X
Journal Announcement: 8408
Document Type: ARTICLE
Language: RUSSIAN
Abstract: The problems of removing metallic inclusions from cold setting mold sands of Al and Mg castings during thermal reclamation are studied. After ten reclamation cycles in a fluidized-bed furnace, chemical and X-ray phase analyses of the metallic inclusions were conducted. Test results showed that the reclaimed sand met established standards. Spent sand used in the reclamation must contain Al <= 0.5%, while Mg content must not exceed 1/10 of the H sub 3 PO sub 4 content of the sand.--J.T.

5/7/60
896062 MA Number: 84-510940

Foundry Waste Management--Current Practice, Future Prospects.
Zayko, R E ; Kunes, T P
Indian Foundry J. 29, (2), 9-13 Feb. 1983 ISSN: 0379-5446
Journal Announcement: 8407
Document Type: ARTICLE
Language: ENGLISH
Abstract: The importance of waste management and resource recovery for efficient planning and operation of foundries is discussed. The technical needs for selecting landfill areas for wastes, sand reclamation, waste recycling and constructive use of wastes are elaborated. Many of the environmental control areas such as preventing wastes, discharges and emissions from entering the water or the atmosphere are discussed.--B.C.

5/7/62
885302 MA Number: 84-510549
Application of UK Sands to the Production of Foundry Moulds and Cores.
Morgan, A D
Foundry Trade J. 154, (3254), 11-15, 22 13 Jan. 1983 ISSN: 0015-9042
Journal Announcement: 8404
Document Type: ARTICLE
Language: ENGLISH
Abstract: After briefly describing the availability and use of sand in moulding, a brief description is given of tests used for the following, clay grade content, particle size analysis, average grain size and A.F.S. number, acid demand, base permeability, sp. surface area, grain shape and green compressive strength. The type and nature of sand required for cores, shell moulding, acid-catalysed resin systems, urethane binders, gas hardening processes, binder-free moulding systems and greensand moulding are described. Finally, reclamation of spent sand is discussed.--R.E.

5/7/63
885220 MA Number: 84-510467
Study on the Application of the No-Bake Molding Process in Manufacturing Precision Machine Tool Castings.
Yang, K H ; Jang, S C ; Jean, M T ; Yang, G C
Chukung (J. Chin. Foundrymen's Assoc.) (38), 10-18 Sept. 1983 ISSN: 0412-3638
Journal Announcement: 8404
Document Type: ARTICLE
Language: CHINESE
Abstract: The surface roughness in the max. height of the machining surface for precision machine tool castings is 35/1000 mm (i.e. approx 35 S). And the 35 S surface roughness or finish is just in the range of the no-bake molding process. The mold is made by applying Australian silica sand mixed with the different proportions of resin and catalyst. To obtain optimum operating conditions, the mixing condition, compressive strength, work and strip time, permeability, surface stability index, elevated temp. properties, influence of the contamination of the sodium silicate sand, LOI, the surface roughness and dimensional accuracy were studied. The reclamation of the no-bake sand solves the pollution problem of disposal of waste sand. 12 ref.--AA

5/7/65
819961 MA Number: 82-511091
Making Your Foundry's Waste Work for You: Constructive Use and Reclamation.
Smith, M E ; Stephens, W A ; Kunes, T P
Mod. Cast. 72, (5), 43-45 May 1982
Journal Announcement: 8209
Document Type: ARTICLE
Language: ENGLISH
Abstract: Constructive and economical uses of foundry wastes are considered. Present alternatives include reclamation of waste material in-plant or by off-site recyclers and the use of sand and other wastes for construction fill, municipal waste landfill or foundry waste landfill. Keeping an eye on federal and local regulations for hazardous and nonhazardous waste disposal, substantial cost savings can be realized by imaginative use of waste materials. Two case examples of waste material usage are presented that resulted in considerable savings to individual foundries.--G.P.K.

5/7/67
765208 MA Number: 81-510485
Phenols in Foundry Waste Sand.
Johnson, C K
Mod. Cast. 71, (1), 48-49 Jan. 1981
Journal Announcement: 8105
Document Type: ARTICLE
Language: ENGLISH
Abstract: Potential environmental problems from phenolic foundry binders are considered in light of the EPA regulations concerning waste sand disposal. Phenols give drinking water a bad taste and are therefore kept below 1 ppb. The waste sand from foundry processes provide a source of phenol to wastewater and run-off supplies. Maintaining a low sand to metal ratio and high casting temp. minimizes the presence of phenols. However, phenols are not a serious long-term problem since biodegradability is a characteristic of all phenols. Common sources of phenols show man and wildlife to be somewhat tolerant to this compound and small, incremental releases into wastewater can be handled by natural processes. Unfortunately, heavy metals are often associated with the phenol release and this is a more serious toxicity problem.--R.M.G.

5/7/70
723792 MA Number: 80-510778
Environmental Assessment of Decomposition Products From Cores and Molds.
Baldwin, V H
Conference: 83rd Annual Meeting, Birmingham, Ala., 30 Apr.-4 May 1979
Publ: American Foundrymen's Society, Golf and Wolf Rd., Des Plaines, Ill. 60016, 1980
87, 617-618
Journal Announcement: 8008
Document Type: BOOK
Language: ENGLISH
Abstract: Sampling of ductile Fe castings in green sand molds with

phenolic isocyanate cores and in phenol-formaldehyde bonded shell molds did not provide definitive proof that environmentally hazardous organic emissions occur. Both molding systems produced the same type of major emissions, alkyl halides, carboxylic acid derivatives, amines, substituted benzenes, nitrogen heterocyclics and fused aromatics in quantities that slightly exceed the lowest minimum acute toxicity effluent (MATE) values for the categories, but probably not for individual compounds. Gas chromatography--mass spectrometry (GC--MS) analysis revealed the major fused aromatics to be naphthalene compounds. Quantitative analysis of specific carcinogens showed no significant level of concern. Inorganic dust emissions are hazardous if uncontrolled because of Si, Cr and Ni. The dust is sufficiently high in 12 metals to render it a hazardous waste if collected as a sludge and landfilled, but leachate testing may change that categorization. Relatively high levels of Zr, Ba, Ce, Pr and Nd in the dust indicate that inoculation smoke should be examined.--AA

5/7/71
706480 MA Number: 80-720076
82nd Annual Meeting.
Detroit, Mich., 24-28 Apr. 1978
Publ: American Foundrymen's Society, Golf and Wolf Rd., Des Plaines, Ill., 1979
Pp 636, 81/2 x 111/4 in., Illustrated
Journal Announcement: 8002
Document Type: BOOK
Language: ENGLISH
Abstract: Contents include: M.M. SHEA, "Influence of Cooling Rate and Copper Content on Hardness of As-Cast Ductile Iron"; M.M. SHEA HOLTAN, "In-the-Mold Treatment Using Elemental Magnesium to Iron"; M.M. SHEA, "Influence of Composition and Microstructure on Cracking of Gray Cast Iron"; R.S. LEE, "An Engineering Approach and Risering"; V.H. PATTERSON and M.J. LALICH, "Fifty Cast Iron Inoculation"; J.A. CAPADONA and D.L. Testing as Applied to Lost-Polystyrene Investment Casting"; R.B. "Elevated-Temperature Properties of Alloyed Gray Irons for Diesel Components"; E.J. SIKORA, "Evaporative Casting Using Expandable Patterns and Unbonded-Sand Casting Techniques"; A.E. UMBLE, Simulation for Determining Chilling Practice on Cast Steel Rolls"; SCHEID, "Control of Refractory Erosion in Holding Furnaces"; K. "Thermal Fatigue of Gray and Ductile Irons"; R.F. FIRGARD, Approach to Coldbox Tooling to Increase Quality and Reduce Cost"; "Characteristics of As-Cast and Subcritically Heat Treated High-Chromium--Molybdenum White Irons for Thick-Section Castings"; PILLAI, V. PANCHANATHAN and U.D. MALLYA, "Chill Dimensions of Long-Freezing Range Aluminum Alloys"; G.S. MAIER and J.W. WALLACE, "Spheroidization of Graphite Nodules Iron"; R.D. PEHLKE, H. WADA and G.R. STRONG, Production"; S.A. LEVY, "Techniques for Improving Ductility of Diecast Aluminum Wheels"; L.J. VENNE and C.Z. OLDFATHER, Physical Properties by Argon Oxygen Decarburization"; A.F. in Compacted Graphite Iron"; R.A. HENRY, "Metal-Coated Production/Low-Cost Tooling Systems"; J.M. DONG, W.A. "Effects of Barium/Cerium Combinations in Magnesium--Ferrosilicon on Iron"; E.J. DUCKETT, "Effects of Aluminum as a Contaminant of Recovered From Municipal Refuse"; M. SOFUE, S. OKADA and T. "High-Quality Ductile Cast Iron With Improved Fatigue Strength"; SKUBON,

"Microwave Curing of Core Binders and Coatings"; C.F. "Energy Savings With Covered Pouring Ladles and Cupola Troughs"; D.F. LaCOUNT and G.M. BAKER, "A Production Hardness Tester Steels"; C.F. LANDEFELD, "Inductive Heating of Coreless Linings"; T.R. OSTROM, R.A. FLINN and P.K. TROJAN, Dissolved Gases Evolved From a Molten Red Brass and an Aluminum KOTTKE and A.E. BLOOMQUIST, "A New Application for Warm-Box Process"; R.M. PILLAI, V. PANCHANATHAN and Temperature for Evaluation of Thermal Parameters"; G.S. COLE, Microwave Heating on Core Processing"; B.A. KOSARIN, "A to Cupola Emission Control Systems"; K.P. COOPER and C.R. Properties of Compacted Graphite Cast Iron"; L.A. NEUMEIER and "A New Look at Nodulizing Ductile Iron With Yttrium and Mischmetal Additives"; K.P. COOPER and C.R. LOPER, JR., "A Critical Production of Compacted Graphite Cast Iron"; B.C. GODSELL, of Ductile Iron"; R.J. PAZARA, "Recent Developments in Foundry Refractories"; U. EKPOOM and R.W. HEINE, "Austenite Temperature Range in Cast Irons"; J.W. DAVIS and A.B. Operating Parameters in Cupola Furnaces on Particle Emissions"; S. "Fluidization of Basic Slags and the Role of Calcium Fluoride E.A. LANGE, "Fracture Toughness Measurement and Analysis for Castings"; J.-L. DION, A. COUTURE and J.O. EDWARDS, for High-Conductivity Castings"; A.L. GRAHAM and R.M. Blue Testing of System Sands and Preblended Additives"; H.L. BORIK, "Optimizing the Toughness and Abrasion Resistance of Austenitic 6Mn--1Mo, 8Mn--1Mo and 12Mn--1Mo Steels"; R.A. FLINN, Chemical Effects of the Oxygen Jet in Liquid Steel"; R.L. NARO TENAGLIA, "Influence of Nobake Binder Processing Variables on Penetration in Gray Iron Castings"; A. PETRO and R.A. FLINN, Interactions Between Chromite Sand and Cast Steel"; R.W. HEINE SCHUMACHER, "Clay Evaluation as a Green Sand Control ASKELAND and R.F. FLEISCHMAN, "Effect of Nodule Count Properties of Ferritic Malleable Iron"; K.G. DAVIS, R.K. MAGNY, "Dissolution of MgFeSi Alloy During Inmold Treatment"; J. O. EDWARDS, "The Kappa Phase in Nickel--Aluminum Bronze. Microstructures"; R. THOMSON and J.O. EDWARDS, "The Nickel--Aluminum Bronze. II.--Cast Microstructures and Properties"; and W.S. HYLER, "An Analysis of the Mechanical Properties of the Aluminum Casting Alloy"; M. SVILAR and J.F. WALLACE, From Gray Cast Iron to Reduce Pinholes"; M.S.R. PRASAD, M.N. M.R. SESHADRI, "Using Insulating Materials for Feeders Heads Castings"; R.D. WARDA and R.K. BUHR, "A New Cupola Dust KUNES, "Waste Characterization and Analysis--a Key to Disposal"; and R.D. PEHLKE, "Application of Computer-Aided Design to a Casting"; R.A. FLINN, J. KEOUGH, J. BIEL and R. Designs--Permanent Mold Copper Alloy Castings"; D.L. Risering Austenitic Ductile Irons"; F.R. MOLLARD and N. Foam: a Unique Method of Filtering Aluminum Castings"; A.B. and J.W. ROBISON, "Supplementary Air to Minimize Carbon Effluent"; F.W. ROHR, "The Economics of Sand Reclamation as Disposal"; F.R. MOLLARD and N. DAVIDSON, "A Technique for Aluminum Alloy Melts"; A.S. AMIN and C.R. and Rare Earths in Ductile Cast Irons"; K.G. WIKLE, "Improving Castings With Beryllium"; V.K. GUPTA and M.W. TOAZ, "New a State of the Art Review"; A.B. DRAPER and J.G. SYLVIA, Technology--Key to Reduced Melting Energy and Cost"; M. GARAT and "A Review of Recent French Casting Alloy Developments"; V.R. H.W. KILAU and W.M. MAHAN, "Auxiliary Fluxes in Cupola CASTAGNA, P. FERRERO, R. MEDANA and E. NATALE, "In-Mold Ductile Iron"; A. COUTURE, "Influence of Antimony Singly, on the Mechanical Properties of Tin Bronzes"; Y.A. OWUSU DRAPER, "Metamorphic Zones in Green Sand Molds Poured With SCOTT, P.A. GOODMAN and R.W. MONROE, "Gas Generation Interface"; R. MEDANA, E. NATALE and M.S. of Ductile Iron Castings-- "Casting Uniformity--a Close Encounter".

5/7/73
705554 MA Number: 80-510211
Waste Characterization and Analysis--a Key to Disposal.
Kunes, T P
Conference: 82nd Annual Meeting, Detroit, Mich., 24-28 Apr. 1978
Publ: American Foundrymen's Society, Golf and Wolf Rd., Des Plaines, Ill. 60016, 1979
447-452
Journal Announcement: 8002
Document Type: BOOK
Language: ENGLISH
Abstract: A federal regulatory program is established for hazardous wastes management and national criteria are established for the land disposal of all types of solid wastes. Foundry process wastes and pollution control and dust collection residuals are affected by the legislation. Waste characteristics, especially any hazardous properties, and disposal sites and practices will receive particular attention under the Act. Research sponsored by AFS engineering practice have provided methodology and testing techniques for characterization and analysis of a foundry's wastes. This methodology can be used to systematically evaluate a foundry's wastes and waste handling and disposal practices. Results from use of the methodology and testing techniques show differences among foundry wastes in terms of potential environmental effects. Raw materials, production processes, sand reclamation systems and techniques used for pollution control and dust collection all directly affect the quantity and quality of solid wastes from a foundry. Special handling of some wastes may be required.--AA

2/7/5
1300774 NTIS Accession Number: TIB/B87-81644/XAB
Innovation und Umweltschutz in Betrieben der Giessereiindustrie - Ergebnisse von Betriebsbefragungen. (Innovation and environmental protection in firms of the foundry industry - results of questionnaires to firms)
Theissen, A.
Technische Univ. Berlin (Germany, F.R.). Wirtschaftswissenschaftliche Dokumentation.
Corp. Source Codes: 030172031
1987 55p
Languages: German
Journal Announcement: GRAI8807
In German, Technische Universitaet Berlin, Wirtschaftswissenschaftliche Dokumentation. Diskussionspapier, no. 115.
NTIS Prices: PC E09
Country of Publication: Germany, Federal Republic of
This report summarizes the results of a written questionnaire in the field of West German iron foundries on the subject of 'Innovation and environmental protection'. According to this, the melting process in the foundries has become more productive, more energy saving and mostly environmentally acceptable. In the field of moulding, automatically processed moulding materials bound in synthetic resin have succeeded. The regeneration of these moulding materials is not generally practised, in

contrast to the treatment of moulding sand bound with clay, so that this old sand has to be deposited as special waste. More than 80% of the iron foundries are subject to 'Clean Air' regulations, mostly according to the Clean Air Technical Guide (TA Luft) and have taken measures for environmental protection. More severe requirements were made in isolated cases, where one cannot establish any correlation with the size of the firm or its position within a communit. The thesis that large firms are more frequently subject to official inspection could not be supported by the data of our sample. One explanation of this may be that the authorities accept the measurements of environmental consultants which the larger firms employ and therefore do not take their own measurements. Measurements during inspections by the authorities are the exception rather than the rule. (orig./RHM). (Copyright (c) 1987 by FIZ. Citation no. 87:081644.)

2/7/6
1268876 NTIS Accession Number: TIB/B87-80453/XAB
Labormaessige sowie praxisbezogene Ausfuehrung von Regenerierungsprozessen, wie sie in der Aufbereitung von Giessereischutt anfallen koennen. Schlussbericht. **(Avoidance, Reduction or Utilization of Production Residues from a Foundry. Final Report.)**
Jaeger, E. ; Hupfeld, R. ; Outziolas, G.
Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.).
Corp. Source Codes: 057110000;
Sponsor: Duisburg Univ. (Germany, F.R.). Forschungsgruppe fuer Belastungsmessungen und Giessereitechnologie.
Report No.: BMFT-FB-T--86-127
1986 119p
Languages: German
Journal Announcement: GRAI8720
In German. With 10 refs., 25 tabs., 69 figs.
NTIS Prices: PC E11
Country of Publication: Germany, Federal Republic of
Contract No.: 1430307
In the field of regeneration of foundry refuse, specifically organically bound sand, different mechanical, wet chemical and thermal methods of regeneration were analysed. For assessment of sand reactions, regarding the technology of casting, the regenerated sand was processed. The results show that a high temperature regeneration (800 deg C) is not necessary, a regeneration with temperatures of maximum 450 deg C is enough to produce a high-grade recycling material, and to reduce energy costs. (orig.). (Copyright (c) 1987 by FIZ. Citation no. 87:080453.)

3/7/3
468354 PR
USE OF WASTE PRODUCTS IN HIGHWAY CONSTRUCTION
INVESTIGATORS: Whited, GC
SPONSORING ORG: Wisconsin Department of Transportation
PERFORMING ORG: Wisconsin Department of Transportation Division of Highways and Transportation Services 4802 Sheboygan Avenue Madison Wisconsin 53707
PROJECT START DATE: 87
PROJECT TERMINATION DATE: ND

SUBFILE: HRIS
Project includes the use of various industrial waste products (fly ash, foundry sand and bottom slag) as highway embankments and sub-base material, and investigates the construction problems, performance characteristics and environmental impacts of each.

1/7/1
128423 87-03930
Alternative sought to landfilling of foundry sand
Anon.
ERRI NEWSL VOL. 17, NO. 3, pp. 2, 4, Publ.Yr: 1987
Languages: ENGLISH
Foundries are a major generator of industrial solid waste in Pennsylvania. The Commonwealth has about 250 foundries, specializing in ferrous or nonferrous products and employing approximately 20,000 people. The gray iron foundries melt down scrap iron to cast such things as valves and pipes. In making various castings, the foundries use large quantities of sand mixed with chemical binding agents and water to form molds. After use, the sand--about 1 million tons annually--must be disposed of in licensed landfills.

1/7/3
078856 81-07318
Leachability of Foundry Process Solid Wastes
Ham, R.K.; Boyle, W.C.; Kunes, T.P.
Civ. & Environ. Eng., Univ. WI, Madison
J. ENVIRON. ENG. DIV. ASCE VOL. 107, NO. EE1, pp. 155-170, Publ.Yr: 1981
Languages: ENGLISH
A laboratory procedure was developed for testing the leachability of foundry process solid wastes. This procedure uses a shake-flask technique to provide distilled water-foundry waste contact, plus filtration or centrifugation, or both, to separate the resulting liquid for analysis. The procedure was used to examine the leaching characteristics of eight different foundry process wastes, each of which had been previously subjected to temperature ranging from room temperature to temperature of molten metal. This was done to simulate the burn-out which would actually be experienced with some wastes. The eight wastes exhibited widely different leaching characteristics, but in all cases the amount of matter leached per unit weight of water decreased markedly as the temperature to which the waste was subjected increased. Additional experiments utilizing the shake-flask procedure indicated that progressively larger particles of waste, such as core butts, release less matter to leachate per unit weight of waste than the unagglomerated sand.

1/7/5
057467 79-01906
Utilization of wastes and byproducts as construction materials in Canada.
Emery, J. J.
McMaster Univ., Hamilton 16, Ont. L85 4L7, Can.

First Recycling World Congress Basel, Switz. Mar. 6-8, 1978
First Recycling World Congress: Proceedings Publ.Yr: 1978 pp. 1/12/i-1/12/xv
Publ: Oxted, Surrey, Eng. Recycling World Congress
illus. refs.
Abs.
Languages: ENGLISH
Doc Type: CONFERENCE PAPER

The inherent variability of wastes is the major technical constraint against their use in construction. Type or compositional specifications restrict construction use of waste materials and byproducts; performance criteria do not. Handling, processing, and transportation costs are the limiting factor for waste use. Wastes and byproducts can be divided into 4 categories based on available quantity, distance from point of use, and potential harmful qualities. An inventory of Canadian wastes and reuse potential is presented for the following: blast furnace slags; sulfur; fly ash; steel slags; demolition wastes; Ni and Cu slags; bottom ash; cement kiln dust; bark and sawdust; glass; Fe mine, overburden, cobbings, and tailings; tires; and foundry sand. (SS)